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IN-SERVICE PERFORMANCE OF STUCTURAL DETAILS

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SSC-272 IN-SERVICE PERFORMANCE OF STUCTURAL DETAILS 1978

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AN INTERAGENCY ADVISORY
COMMITTEE DEDICATED TO IMPROVING
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SR-1232

The fabrication of structural design details represents a significant part of a ship's structural cost. These details also represent potential sources of premature failure, fatigue cracking, and, perhaps, spontaneous fracture. Although periodic or pre-repair surveys are made on ships, insufficient information is reported to evaluate the performance of the structural details.

Therefore, the Ship Structure Committee initiated a project to examine 50 ships undergoing repairs or periodic surveys to determine the type and frequency of different structural details and pin-point those areas where problems have occurred.

This report describes the results of that project. An additional 36 ships are now being examined.

W. M. Benkert
Rear Admiral, U.S. Coast Guard
Chairman, Ship Structure Committee

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FINAL TECHNICAL REPORT

on

Project SR-1232

"Structural Details Failure Survey"

IN-SERVICE PERFORMANCE OF STRUCTURAL DETAILS

by

C. R. Jordan
C. S. Cochran

NEWPORT NEWS SHIPBUILDING

under

Department of the Navy
Naval Sea Systems Command
Contract No. N00024-76-C-4362

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U. S. Coast Guard Headquarters
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1978

ABSTRACT

This report includes the results of a structural detail survey of twelve families of approximately fifty different ships. Seven ship types were surveyed to determine whether or not predicted failures actually occurred.

The families are beam brackets, tripping brackets, non-tight collars, tight collars, gunwale connections, knife edge crossings, miscellaneous cutouts, clearance cuts, deck cutouts, stanchion ends, stiffener ends, and panel stiffeners. Fifty-six groups evolved with a total of 553 observed variations in structural configuration. The data are synthesized by family groups.

During the survey 490,210 details with 3,307 failures were observed. Eighty-two percent of the failures were in the cargo space and were predominately located in structure adjacent to the side shell. The remaining 18% were distributed, 10% forward and 8% aft of the cargo spaces.

Feedback data of this type should be invaluable to design and repair offices. It depicts, with sketches and photographs, the variations of structural configurations and tabulates all of the data collected during the survey. As an aid to engineers and designers, failure causes such as design, fabrication, maintenance and operation are postulated. Systematic performance studies of this type should be conducted in all areas of ship construction.

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INTRODUCTION

On January 9, 1976, Newport News Shipbuilding received a contract from the Department of the Navy, Naval Sea Systems Command, Code: SEA 0242 to perform the Ship Structure Committee project SR-232. This project, under the advisorship of the National Academy of Sciences, Ship Research Committee, was to conduct a structural detail failure survey of twelve detail families on approximately fifty different ships. The twelve families of details were to be surveyed by an on board visual inspection of several ships of various types, undergoing repairs or periodic surveys, to determine whether or not predicted failures actually occurred.

The goal of the project is to provide design and repair personnel with structural service data and recommendations that can be used to significantly decrease the number of detail failures that occur in ships which operate in an environment that is constantly changing, inconsistent, and often times hostile. Current design and repair practices are based on theory and empirical data that produce satisfactory performance except in relatively isolated cases which have vulnerable areas of instability in localized structural arrangements. Failures that do occur, however, are usually in the plate crack or buckle modes and must be repaired or confined to the local area to prevent a threatened total collapse of the ship structure.

A number of structural details that are common to many ships are examined in the survey in order to evaluate the effectiveness of various existing geometrical configurations that have been used for similar shipboard conditions. Data from sound and failed details are gathered from interviews, repair specifications, and inspections aboard ships which are undergoing repairs or periodic surveys in repair yards or aboard accessible ships at loading and unloading docks. Results from the orderly and systematic study of structural details on ships in service can make a significant contribution to design and repair knowledge that should result in an improvement in design and fabrication practices and increase the number of sound details in present and future ships.

Structural details that have histories of failures in the past were selected on the basis of References 1, 2, and 3, and from preliminary interviews with ship design and repair personnel. After grouping the observed details according to their intended functions, a typical configuration for each of the twelve detail families was selected as a basis for discussing the variations within each family. These typical configurations, as shown in Figure 1, were selected according to their maximum frequency of occurrence on the ships surveyed.

This method of classification provided for inclusion in the survey of other details; ones that did not have known failure histories but were expected to be vulnerable to the magnifying stress patterns imposed on the local structure by the detail geometry, fabrication methods and other environmental factors such as corrosion. Also included were the numerous sound and successful details that have remained strong and functionally effective throughout many years of ship service.

FIGURE 1

DETAIL CLASSIFICATIONS

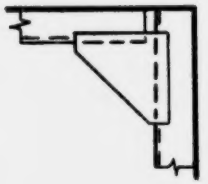
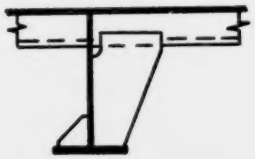
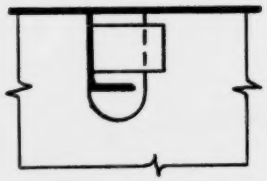
Type No.	Name	Functional Provision	Typical Configuration
1	Beam Bracket	Increase strength of framing and stiffening members at their supports.	
2	Tripping Brackets	Laterally support framing and stiffening members.	
3	Non-Tight Collars	Provide a connection from webs of framing and stiffening members to the plating of supports that have cutouts at the members.	

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FIGURE 1, Detail Classifications (Cont'd)

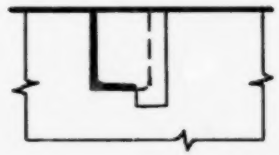
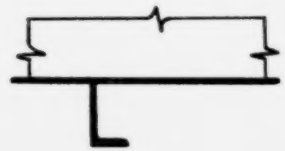
Type No.	Name	Functional Provision	Typical Configuration
4	Tight Collar	Same as 3. above except also cover the cutouts to prevent passage of fluid or objects through the cutout.	
5	Gunwale Connection	Join the strength deck stringer plate to the shear strake.	
6	Knife Edge Crossing	No functional provision	

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FIGURE 1, Detail Classifications (Cont'd)

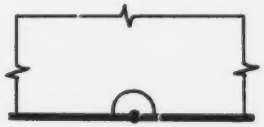
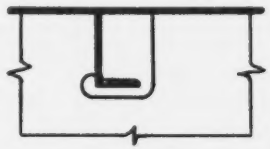
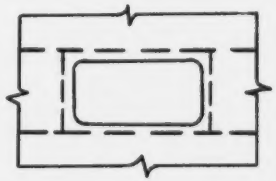
Type No.	Name	Functional Provision	Typical Configuration
7	Miscellaneous Cutouts	Provide a wide variety of holes for access, drainage, ease of fabrication, cableways, pipes, stress relief, etc.	
8	Clearance Cutouts	Provide a hole in an intersecting member to allow another member to go through.	
9	Structural Deck Cuts	Allow passage through decks for access, tank cleaning, piping, cables, etc.	

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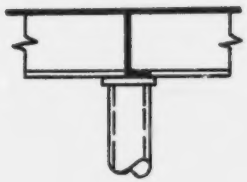
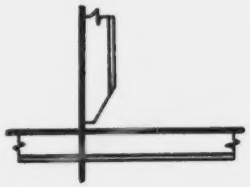
FIGURE 1, Detail Classifications (Cont'd)

Type No.	Name	Functional Provision	Typical Configuration
10	Stanchion Ends	Transfer loads between stanchions and deck supporting members.	
11	Stiffener Ends	Connect an unbracketed non-continuing stiffener to a supporting member.	
12	Panel Stiffeners	Stiffen plating and webs of girders. These are non-load carrying members.	

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SHIPS IN THE SURVEY

Various merchant and naval vessels were surveyed as shown in Table 1. The merchant ships are presented according to their commercial classification and, for national security reasons, the naval ships presented as one class. Included in the table are columns giving the average lengths between perpendiculars, displacements, and ages. These averages vary over ranges of 430 to 770 feet for LBP, 11,000 to 71,000 long tons for displacement, and four to thirty years for age. Of the fifty ships surveyed, forty-two were built or converted in sixteen different domestic shipyards and the remaining eight were built or converted in four different foreign shipyards.

TABLE 1

SUMMARY OF SHIPS SURVEYED

No. of Ships	Classification	Avg. LBP (feet)	Avg. Displmt. (long tons)	Avg. Age (years)	No. Built	
					USA	Foreign
4	Bulk Carriers	618	46,300	10	1	3
5	Combination Carriers	782	43,300	8	5	0
12	Containerships	622	27,500	11	10	2
5	General Cargo	490	18,300	11	3	2
2	Miscellaneous	505	28,600	10	1	1
9	Naval			13	9	0
13	Tanker	630	42,600	19	13	0
50	AVERAGE/TOTAL	622*	34,980*	13	42	8

* Does not include size of the naval vessels.

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SHIPYARDS VISITED AND CONDITIONS OF SURVEY

All of the ships, except one miscellaneous vessel at a Gulf Coast loading dock were in repair yards for scheduled maintenance and periodic inspections, overhauls, or for unscheduled emergency repairs. Thirty-three ships were surveyed at Newport News. The remaining seventeen (17) that were surveyed elsewhere included one bulk carrier, one combination carrier, one general cargo ship, one miscellaneous vessel, nine naval vessels, and four tankers.

A complete list of the yards in which the ships were surveyed are:

Newport News Shipbuilding, Newport News, Virginia

Norfolk Naval Shipyard, Portsmouth, Virginia

Norfolk Shipbuilding & Dry Dock Company, Norfolk, Virginia

Jacksonville Shipyards, Inc., Jacksonville, Florida

Bethlehem Steel Corporation, San Francisco, California

Todd Shipyards Corporation, Alameda, California

Bethlehem Steel Corporation, Boston, Massachusetts

Personnel involved with commercial, civil, naval and regulatory operations in these yards and those on the surveyed ship were interested in the project and were very helpful and cooperative. Permission was granted by the Port Engineer and usually the ship's Captain for each survey with the understanding that the ship's name would remain anonymous.

SHIPBOARD SURVEY ENVIRONMENT

Typically, the ships contained some ballast and sometimes one would have a partial or full cargo load aboard. Inspection of the ship's structure was limited to the accessible details in open compartments as given in Table 2. Tanks that were entered had been checked for gas by a yard chemist and certified safe for man and usually, but not always, safe for welding. In a few cases tanks were bypassed because the ladders were considered unsafe for access. (See Figures 2 and 3) Occasionally, access was gained to a normally closed compartment that had been opened for the repair yard's use or for inspection by the United States Coast Guard and/or the American Bureau of Shipping.

Only the structure that was visibly accessible in the open compartments was surveyed. No attempt was made to remove insulation, chip off the paint, strike loose corroded metal, or alter any item that could cause subsequent repair to the vessel. Inspection of the details was aided by the use of a small hammer and pen knife to determine sound metal. Other testing methods such as dye penetrant, magnetic particles, ultrasonic or x-ray techniques were not used. Under no circumstances was the surveyor to disrupt repair operations or alter

TABLE 2

COMPARTMENT ACCESSIBILITY

Compartments	Number Open (%)
Forecastle storerooms	90
Forepeak tanks	30
Chain lockers	40
Forward pump rooms	90
Cargo spaces	46
Inner bottom	1
Fore and aft passageways	100
Miscellaneous deck-houses	30
Public spaces	100
After pump rooms	96
Machinery spaces	98
Fuel oil tanks	2
Potable water tanks	0
Voids	10
Weapons stowage	0
Shaft tunnels	96
Steering gear rooms	80
Main deck-houses	10

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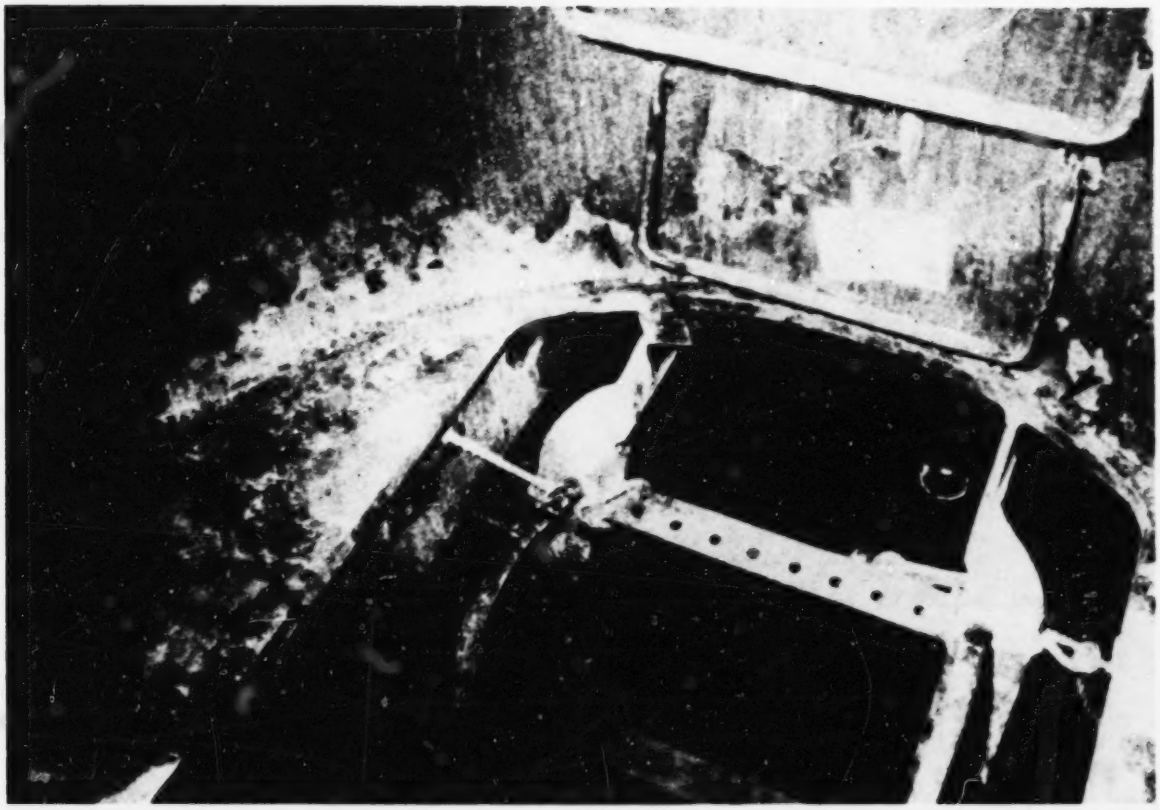
FIGURE 2

FAILED CARGO TANK LADDER CLIPS



The flat bar clips are welded to the underside of the deck and to the ladder frame. A square piece of cardboard has been inserted in the crack in the left-hand clip.

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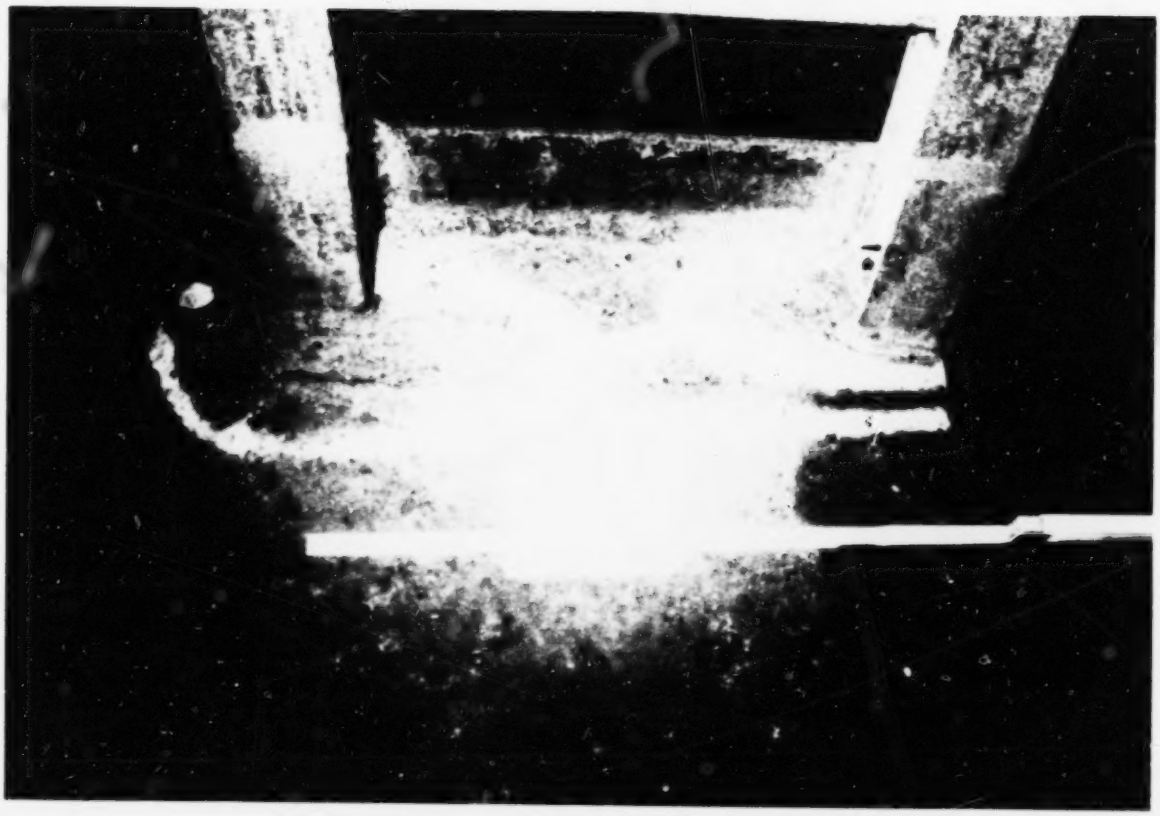
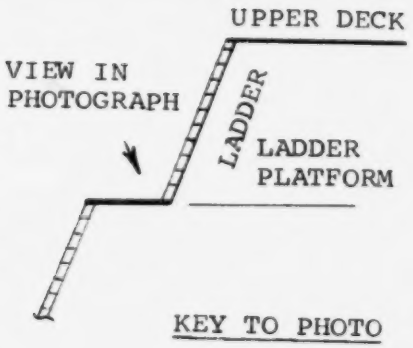
FIGURE 3

CRACKS IN LANDING PLATFORM
FOR CARGO TANK LADDER





KEY TO PHOTO

The cracks are encircled by white paint in order to aid location by repair men. The platform was still intact enough to hold the ladder.

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the existing condition of the ship's structure, to do so was not within the scope of this contract.

Housekeeping on the ships varied from well kept and clean to neglected and unclean. All of the yards required the surveyor to wear a hard hat and safety glasses. Additionally, safety shoes and ear plugs were either required or urged in most of the yards. Other surveyor equipment included coveralls, flashlight, ruler, camera (when permissible) and a notebook of data sheets.

DOCUMENTATION

Quantitative data on the twelve details were accumulated throughout the twelve month period of the ship surveys. The data were collected by the systematic use of the following pre-established check-off list which was developed to ensure that the same type of data was recorded for each surveyed detail. Historical facts were also gathered, when available, for use in the final synthesis.

Ship

- Type
- Size (but not name)
- Age
- Whether domestic or foreign built
- Shaft horsepower

Each Configuration

- Detail family number
- Geometrical sketch
- Location on ship
- Number of details observed
- Estimated number of details
- Number of failed details observed
- Estimated number of failed details
- Failure mode
- Corroded condition
- Weld condition
- Workmanship
- Conformity of parts to shape intended

- Manual or machine preparation
- Material type
- Alignment
- Probable cause of failure

Interviews

- Present structural problems
- Historical structural problems
- Suggestions

The estimated quantity of details with a particular configuration was extrapolated from a count within one compartment or area where that particular configuration prevailed within each ship. Estimated failure quantities were calculated as a function of the observed failed details, repairs requested in specifications, and those mentioned in interviews.

In addition to the recorded data, photographic pictures, where allowed by the owner, were taken of sample sound and failed details on diverse types of commercial ships. Pictures were not permitted on any naval ship.

DETAIL FAMILIES

As the survey progressed it became apparent that each family had various configurations with unique geometrical features that could significantly affect the stress patterns within and around the details. In order to find failure trends in the various features, the details were grouped within each family according to their similar or related characteristics. Thus, each family is composed of two or more detail groups, containing related configurations, which were designed to perform the same function, but differ from each other in one or more geometric features. This grouping method resulted in the twelve detail families being subdivided, see Table 3, into fifty-six separate groups with a total of 553 distinct configurations. The detail variations are identified by their assigned position in the individual families, i.e., the first number(s) is the family number, the letter is the group number and the last number(s) is the variation number.

Each family is presented according to the above grouping with discussions containing sketches of each observed configuration, a summary of each group survey, and sketches and/or pictures of sample failure cases.

TABLE 3

DISTRIBUTION OF DETAIL CONFIGURATIONS

Detail Family Number	Detail Family	Number of Groups	Number of Configurations
1	Beam Brackets	14	125
2	Tripping Brackets	3	66
3	Non-tight Collars	3	36
4	Tight Collars	4	32
5	Gunwale Connections	2	20
6	Knife Edges	0	0
7	Miscellaneous Cutouts	8	65
8	Clearance Cutouts	5	35
9	Deck Cutouts	3	23
10	Stanchion Ends	3	79
11	Stiffener Ends	5	32
12	Panel Stiffeners	6	40
12	TOTAL	56	553

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FAMILY NUMBER 1 - BEAM BRACKETS

Variations in beam bracket configurations are given in Figure 4 and are grouped according to similar characteristics within the continuous, corner, end, and transition functional classification of the bracket. Of the 125 observed variations, forty-four geometrical forms were observed in two or more ship types, and the remaining eighty-one were observed in only one ship type.

Table 4 gives a summary of both the observed and estimated sound and failed bracket details as they existed on the ships. There were no observed failures in the "G" group. Family group "C" appeared more times during the survey and group "J" appeared least. Although group "C" has the highest number of estimated failures, the possibility of failure is only 1.5%. Group "J" has the highest estimated percent failure. All of the group "G" corner brackets were sound although "1-G-5" had a failure history prior to being modified from a curved face plate to the straight one.

The distribution of failures along the ship's length are 10% for the stern aft of the cargo spaces, 75% for the cargo space length, and 15% for the bow area forward of the cargo spaces. Heavy weather, neglect, questionable items, collision, design, and fabrication were the most frequently cited reasons for the failures with heavy weather given as a contributing factor in two-thirds of the failure cases. Twenty percent of the failures were caused by factors which could possibly have been eliminated by the use of a presently congruous design method relative to the stability of unsupported plate edges and stiffness transition factors.

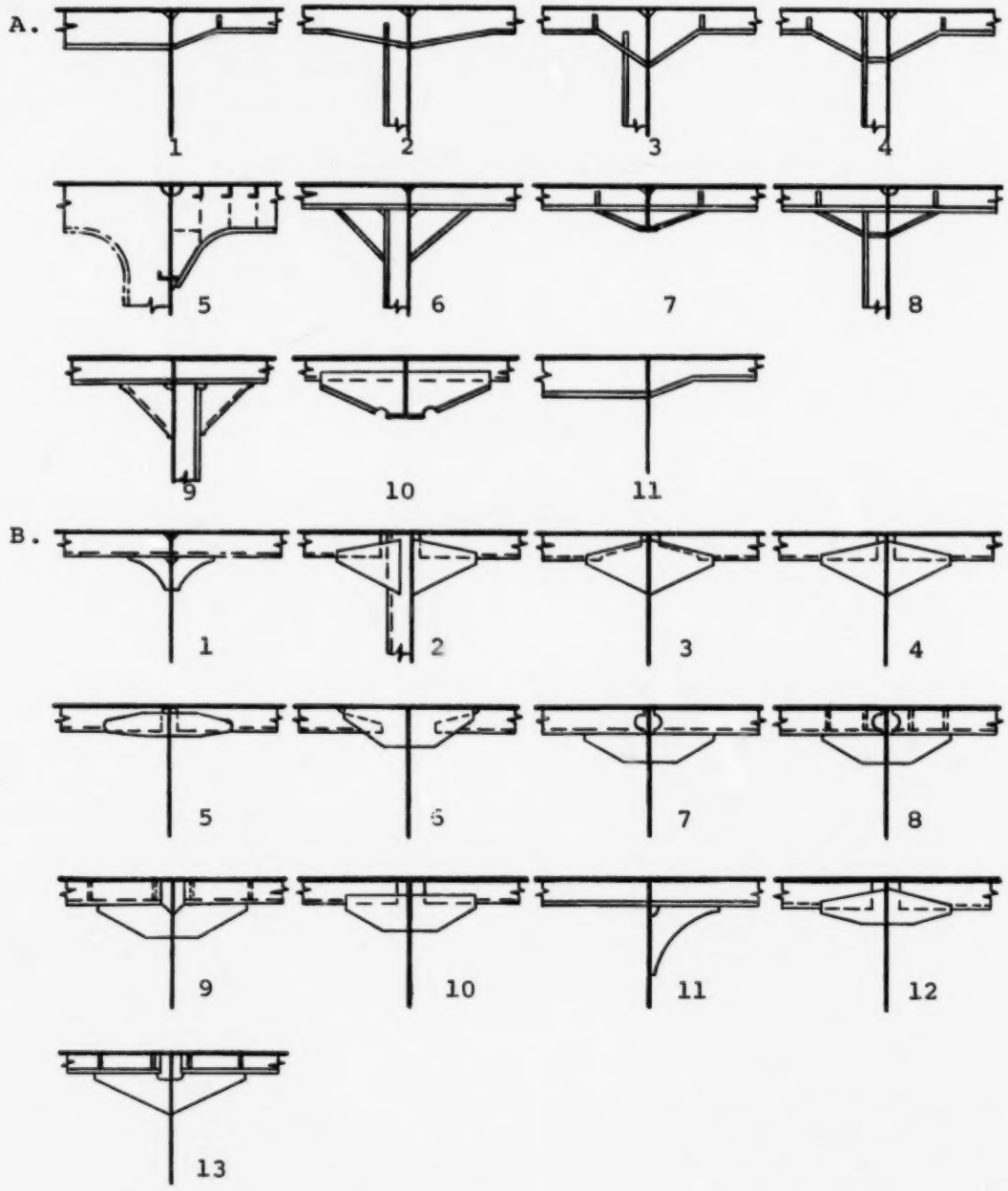
Bracket failures which occurred in the ends of the ship were generally concentrated near the water line where collisions with tugs resulted in dished side shell plating and straited shell frames. Other collisions which caused damage to beam brackets include those of the ship with a pier, possibly another ship or large objects at sea, and grounding. Additional observations about the surveyed beam brackets include:

- Little or no correlation between failures and lapped brackets.
- Tangency chocks should be at ends of bracket face plate (group "A").
- Flat plate brackets and plating panels should be carefully sized to suit stability calculations.
- Brackets near the water line at fore and aft tug stations should be strengthened and have a flange.
- Brackets which land on the inner bottom in machinery spaces and on decks directly under forecastle deck should have scantlings and/or coating to suit corrosive conditions.
- Longitudinals should continue through transverse bulkheads rather than through heavy plate brackets (group "B") which tend to create a hard spot with cracks in the bulkhead plating and connecting stiffeners.

FIGURE 4

BEAM BRACKETS DETAILS
FAMILY NO. 1

CONTINUOUS

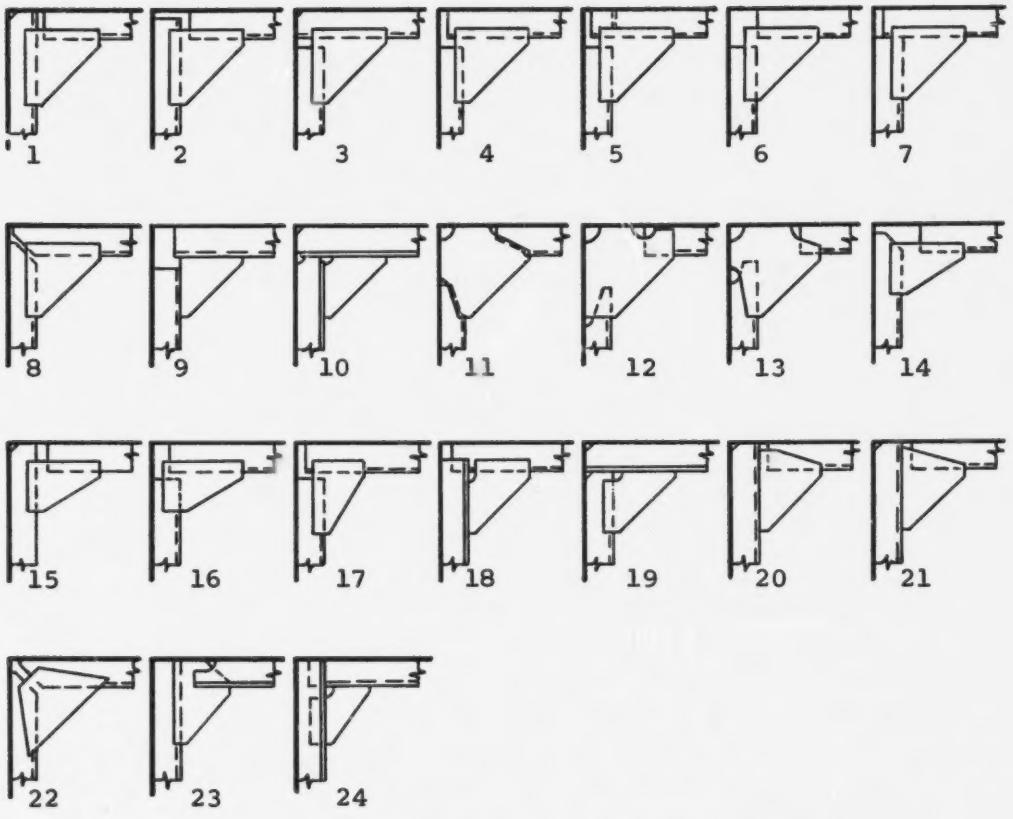


BEST DOCUMENT AVAILABLE

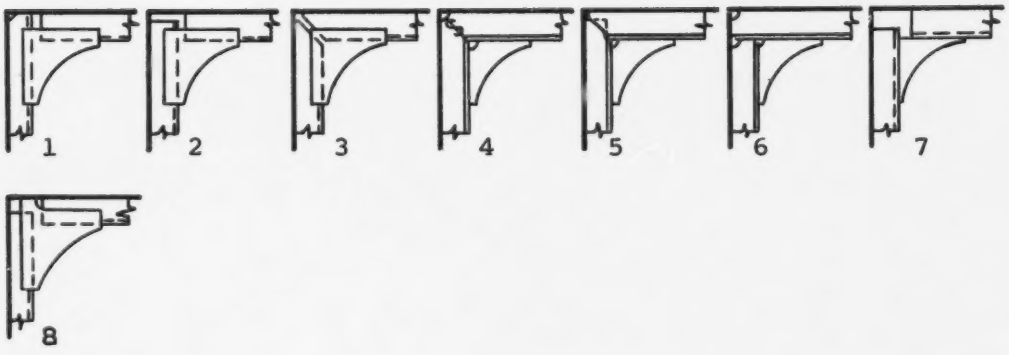
FIGURE 4 - BEAM BRACKETS DETAILS, Family No. 1 (Cont'd)

CORNER

C.



D.

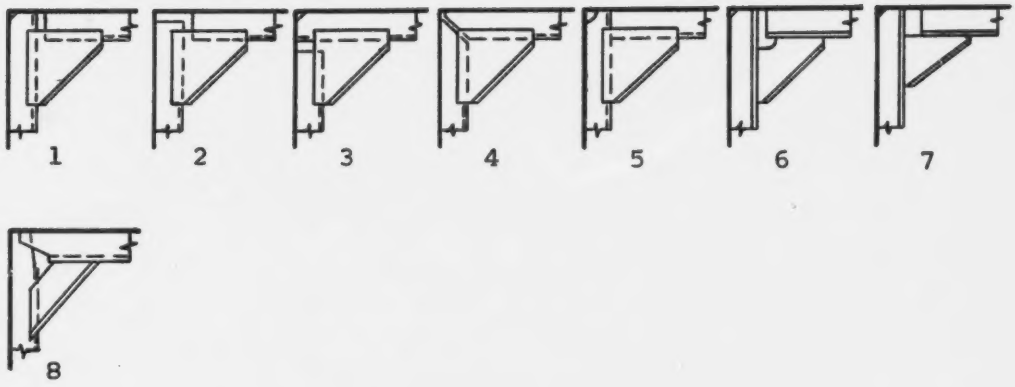


BEST DOCUMENT AVAILABLE

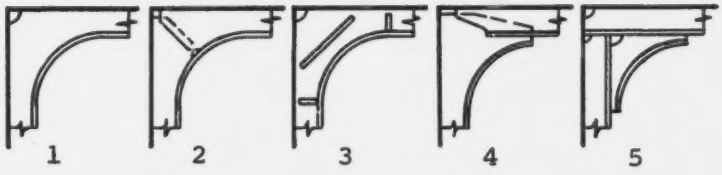
FIGURE 4 - BEAM BRACKETS DETAILS, Family No. 1 (Cont'd)

CORNER (Cont'd)

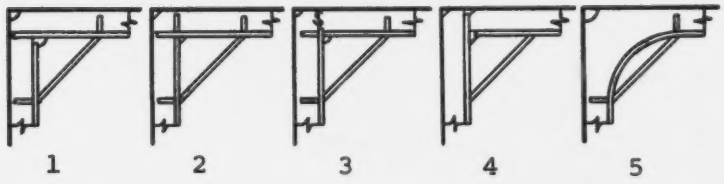
E.



F.



G.

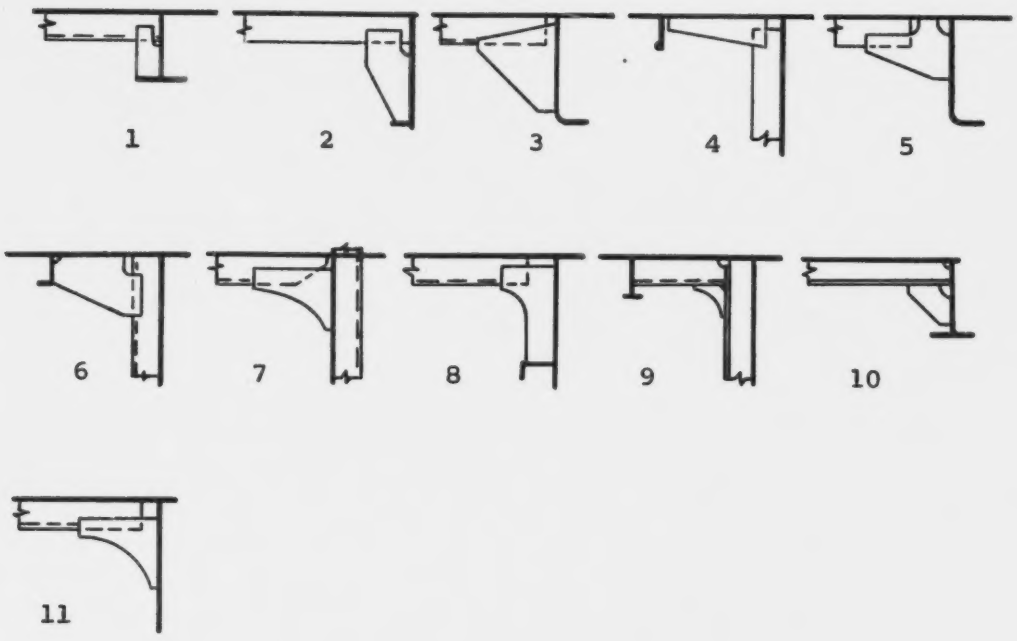


BEST DOCUMENT AVAILABLE

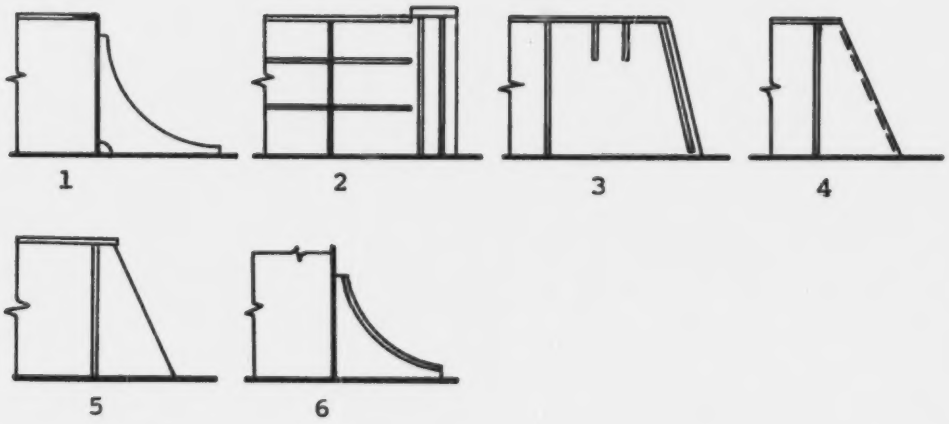
FIGURE 4 - BEAM BRACKETS DETAILS, Family No. 1 (Cont'd)

END

H.



J.

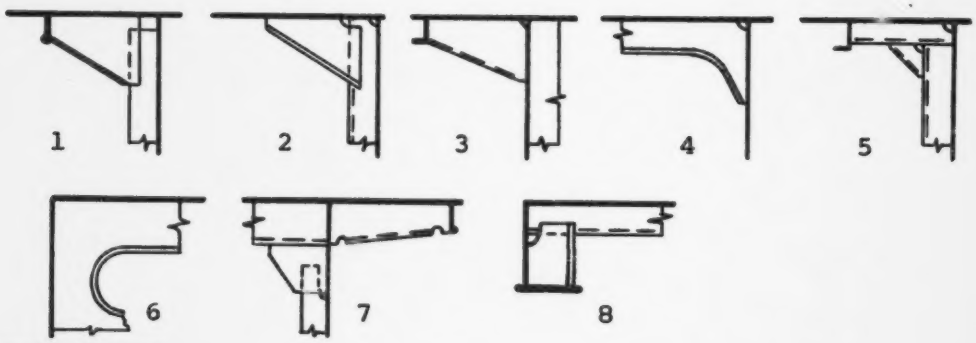


BEST DOCUMENT AVAILABLE

FIGURE 4 - BEAM BRACKETS DETAILS, Family No. 1 (Cont'd)

END

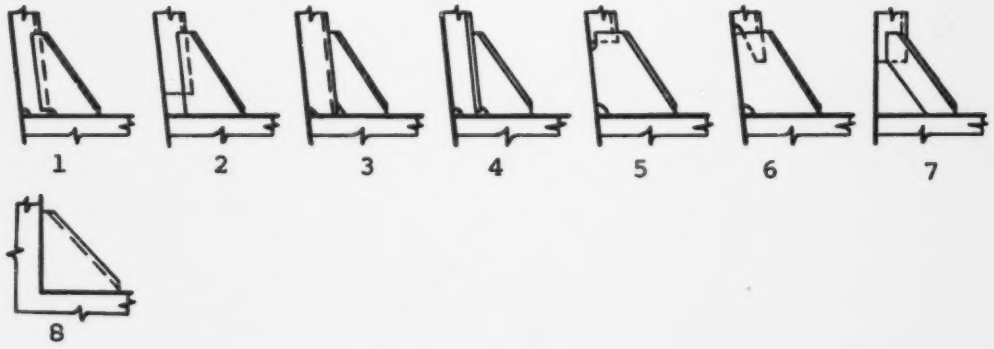
K.



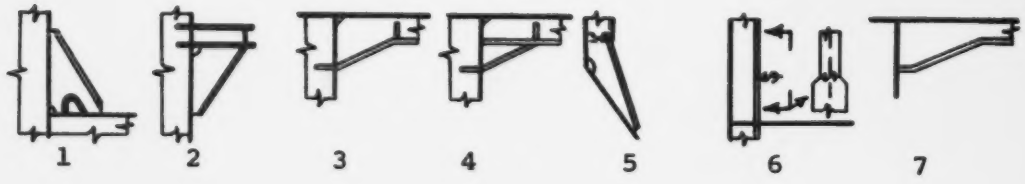
TRANSITION

L.

M.



N.



P.

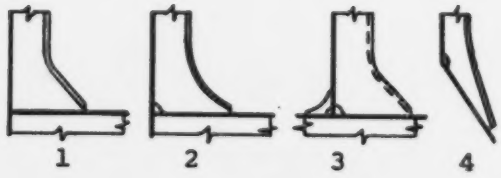


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TABLE 4

SUMMARY OF BEAM BRACKETS

Family Group	OBSERVED			ESTIMATED		
	Number of Details	Sound Details	% Sound Details	Number of Details	Number of Failures	% Failures
a	4950	4928	99.6	12290	24	.2
b	4180	4073	97.4	10070	133	1.3
c	22580	22133	98.0	48320	743	1.5
d	3920	3917	99.9	8750	4	.0
e	1860	1857	99.8	4100	4	.1
f	1050	1022	97.3	2410	35	1.5
g	5040	5040	100.0	12500	-	.0
h	1390	1366	98.3	2830	30	1.1
j	260	211	81.1	260	49	18.8
k	700	666	95.1	1550	46	3.0
l	1060	992	93.6	2360	90	3.8
m	2470	2449	99.1	5320	24	.5
n	630	593	94.1	1470	51	3.5
p	660	615	93.2	1350	64	4.7
TOTAL	50750	49862	98.3	113580	1297	1.1

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- Face plates should not be butt welded in curved corner brackets (group "F").

Sample failure modes in beam brackets are presented in Figure 5 which shows several conditions as they existed on the ships. Cracks are shown occurring in ends of face plates, welds, abrupt member endings, cutouts and in a relatively soft end of a hatch coaming. Buckles are shown as they existed in deck plating, flat bars reinforced by a bracket, flat plate corner bracket, curved face plate brackets and a straight flanged bracket. Three of the sample details have both cracks and buckles in which one type of failure perpetrated the appearance of the other such as in detail 112 where the failure of the bulb bar added to the bending moment in the flanged plate bracket and released the lateral supportive forces at the bracket top.

Figures 6, 7 and 8 are photographs of failed beam brackets in a containership, combination carrier, and a tanker. Figure 6 shows a flat plate corner bracket that buckled due to low plate critical stability level and an unusually high end moment created during heavy weather. The end bracket in Figure 7 has an abrupt ending which contributed to the appearance of the 13 inch horizontal crack just above the weld to the deck. Shown in Figure 8 is a flanged plate bracket that buckled possibly due to a high dynamic head of water on the forecastle while the ship was being "driven" through heavy seas.

FAMILY NUMBER 2 - TRIPPING BRACKETS

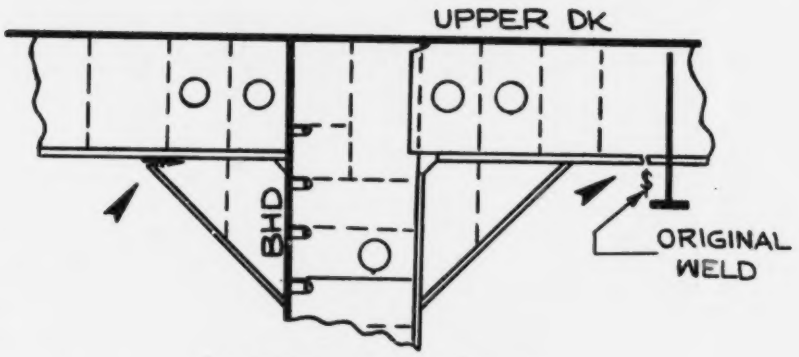
Tripping brackets used to prevent lateral instability failures of webs or flanges of longitudinals, beams or girders are placed in three general groups. Group "A" consists of single plate brackets on one side of the web only; group "B" consists of single plate brackets of the same type located on both sides of the web; and group "C" consists of flanged brackets on one side of the web only. There were no observed cases of flanged brackets on both sides of the web. Figure 9 is the three general group arrangement of the sixty-six variations of tripping brackets seen during the survey period and Table 5 is a summary of observed and estimated data.

The highest failure percentage occurred in group "C" where side loadings on the supported girders created high stresses at the connection of the bracket toe to the deck. Resulting cracks occurred immediately above the weld in the heat affected zone.

Heavy weather and design, followed by a significantly lower rate by welding, misuse/abuse, and collisions, are the most frequent reasons cited for the failures. Two or more reasons are frequently given for a particular failure, such as for detail 2-B-8 where design, welding and heavy weather apparently contributed to the occurrence of cracks in the bracket toes. In this case, it was learned from an interview with one of the ship's officers that the ship had recently encountered a severe storm while the hatches were loaded with three tiers of containers. This combined loading condition developed stresses in the hatch and girder brackets that design had failed to back up with stiffening members under the deck and production had fabricated with

FIGURE 5

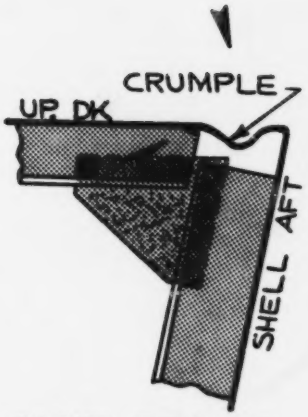
SAMPLE BEAM BRACKET FAILURE MODES



℄ GIRDER NEAR ⊠

DET 100

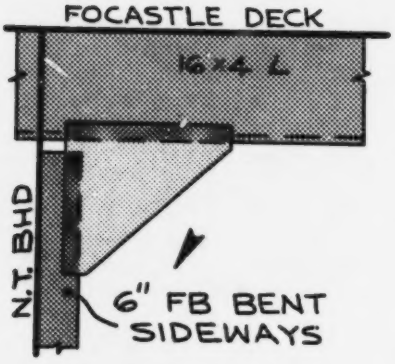
TANKER



CANT FRAME

DET 101

TANKER



TRANS DK GIRDER

DET 102

TANKER

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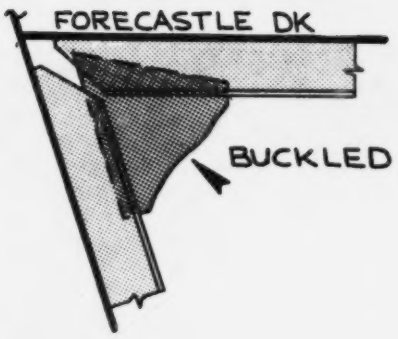
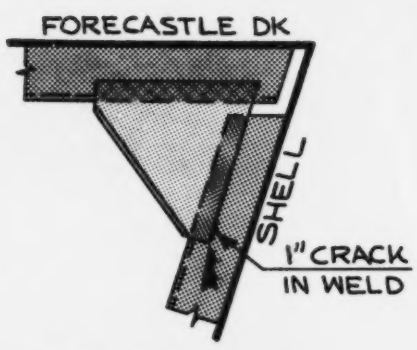
FIGURE 5 - SAMPLE BEAM BRACKET FAILURE MODES (Cont'd)



TRANS FRAMING

DET 103

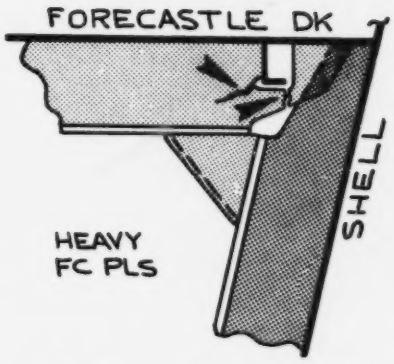
CONTAINERSHIP



TRANS FRAMING

DET 104

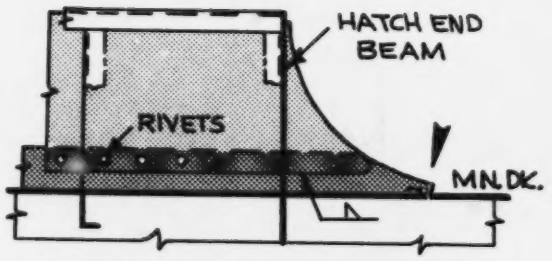
CONTAINERSHIP



TRANS DK GIRDER

DET 105

CONTAINERSHIP



HATCH SIDE GIRDER ENDING
AT CORNER OF HATCH #1

DET 106

CONTAINERSHIP

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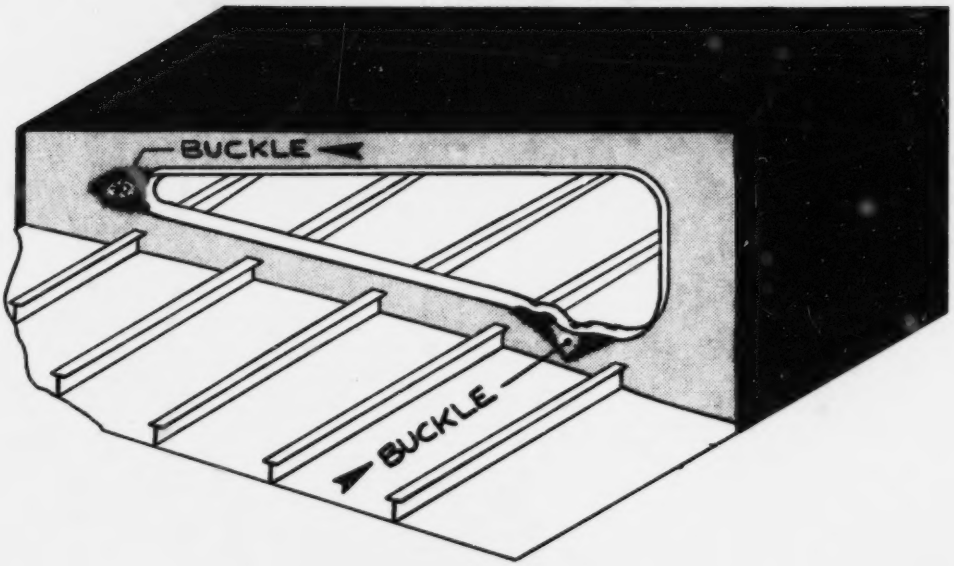
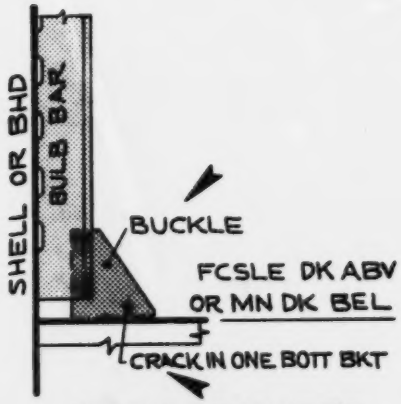
FIGURE 5 - SAMPLE BEAM BRACKET FAILURE MODES (Cont'd)



SHELL FRAMING

DET 107

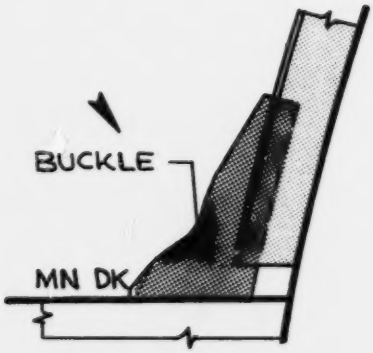
NAVY



VERT STIFFENERS

DET 108

CONTAINERSHIP



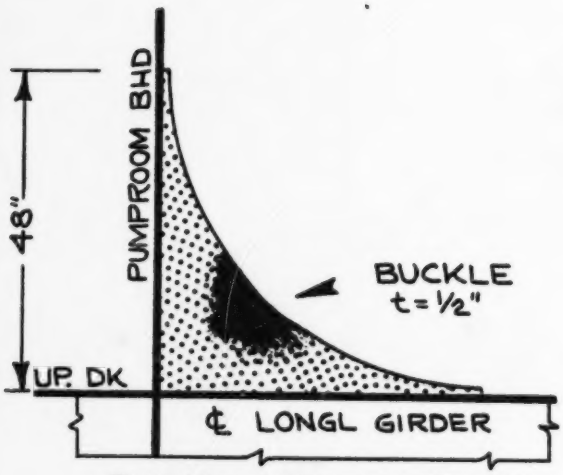
SHELL FRAMING

DET 109

MISCELLANEOUS

BEST DOCUMENT AVAILABLE

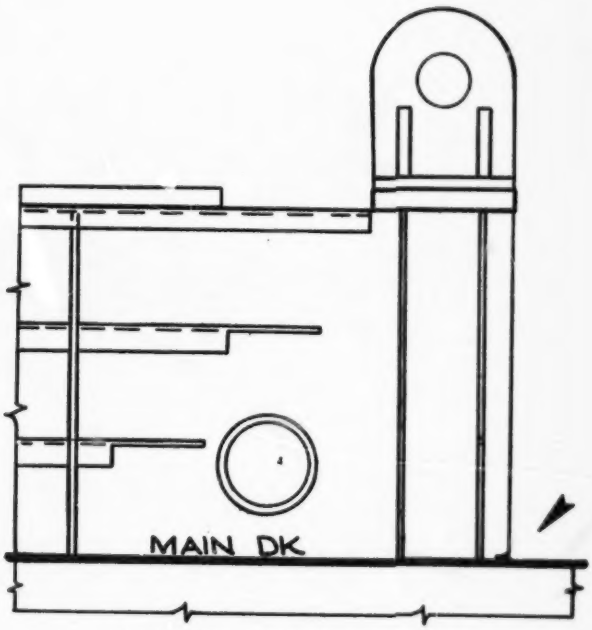
FIGURE 5 - SAMPLE BEAM BRACKET FAILURE MODES (Cont'd)



BKT AT AFT PUMPROOM

DET 110

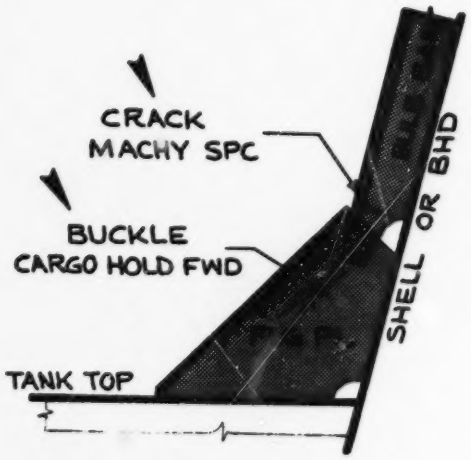
TANKER



HATCH SIDE GIRDER

DET 111

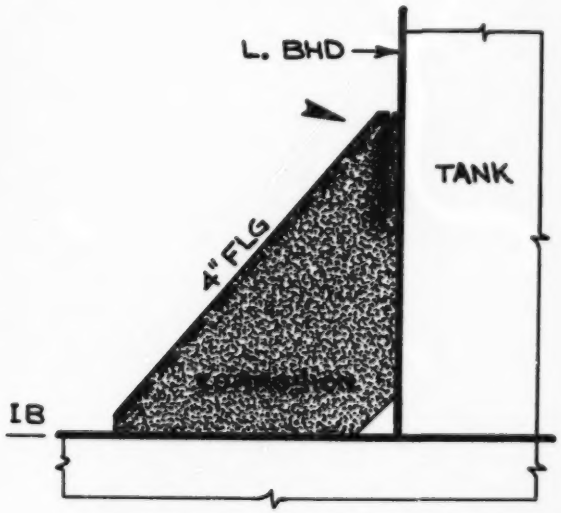
COMBINATION



SHELL & TANK FRAMING

DET 112

CONTAINERSHIP



BRKT. IN MACHY SPACE

DET 113

TANKER

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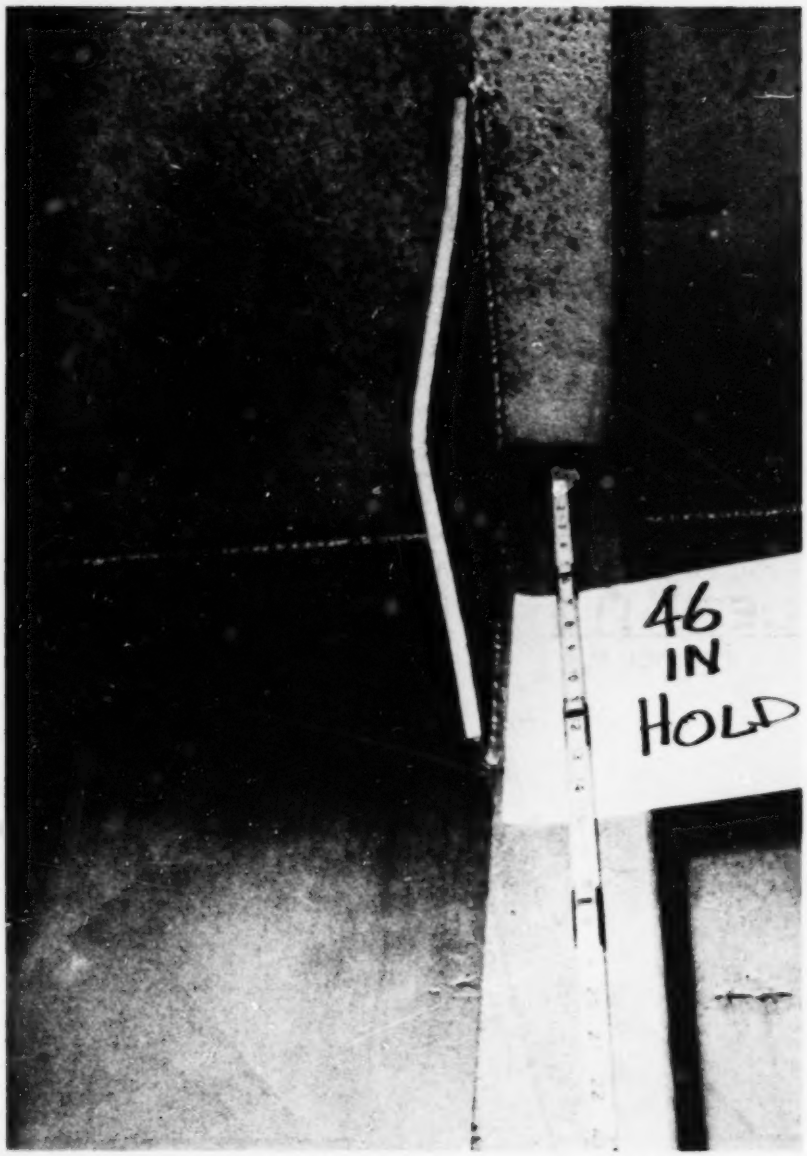
FIGURE 6

FAILED FLAT PLATE CORNER
BRACKET ON A CONTAINERSHIP



The buckled bracket is similar to detail 1-C-1.

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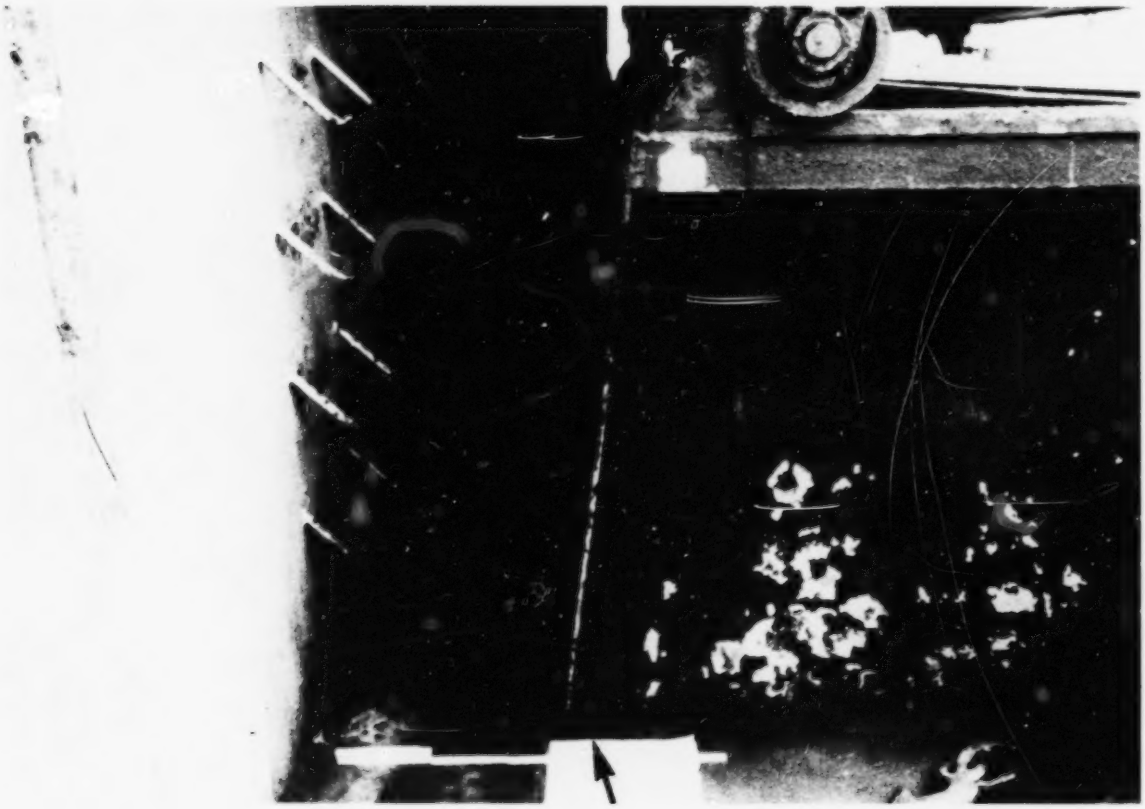
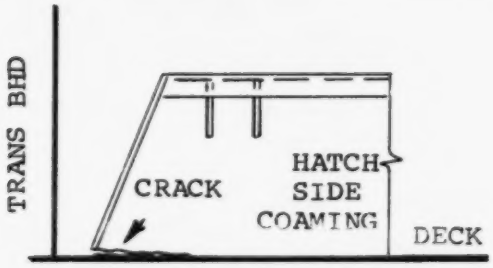
FIGURE 7

FAILED END BEAM BRACKET
ON A COMBINATION CARRIER





KEY TO PHOTO

This photograph shows the end of a hatch side coaming (detail 1-J-3) on weather deck. The ruler is oriented for and aft and parallels the crack in the heat affected zone of the weld to the deck.

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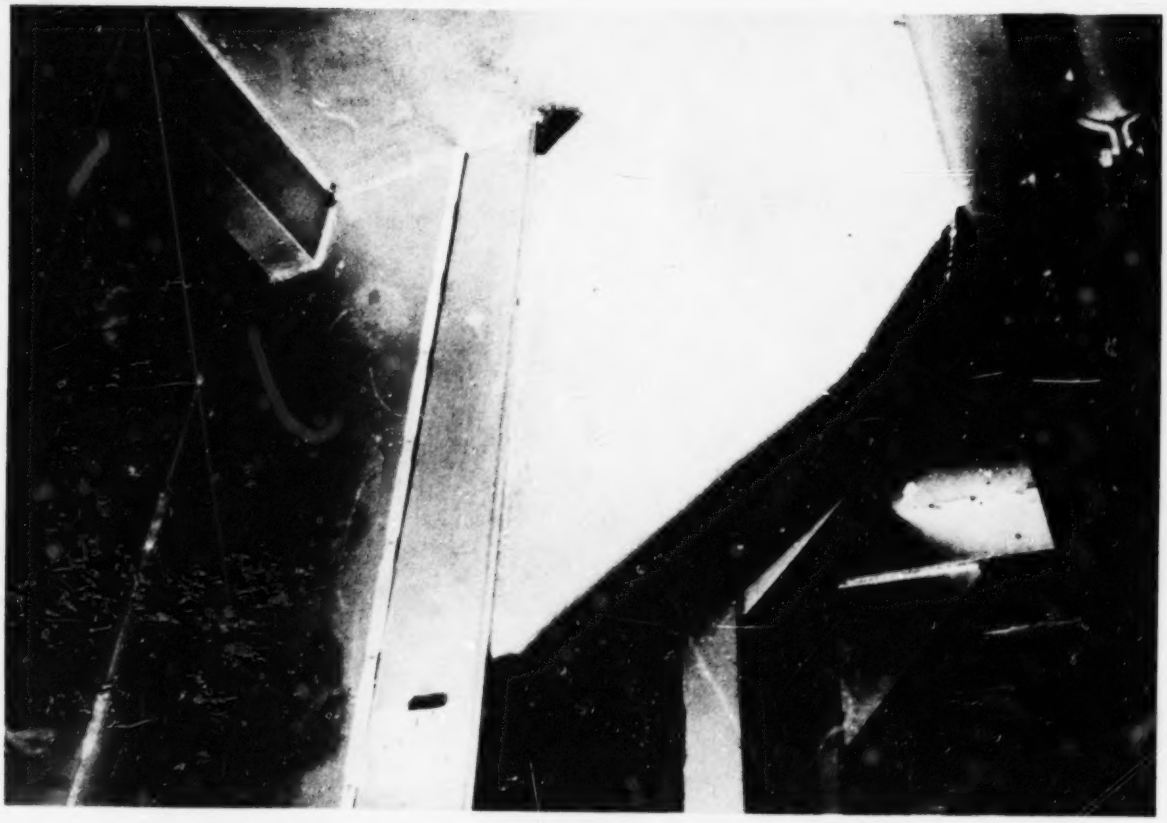
FIGURE 8

FAILED FLANGED PLATE END BRACKET ON A TANKER



The photographer is standing on upper deck and looking up toward forecastle deck. The bracket (similar to detail 1-K-3) is cantilevered in the transverse direction from the chain locker bulkhead and attaches to a deck longitudinal girder on the outboard end. Loading apparently came from on forecastle deck and continued through the deck girder and into the bracket.

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FIGURE 9

TRIPPING BRACKET DETAILS
FAMILY NO. 2

A.

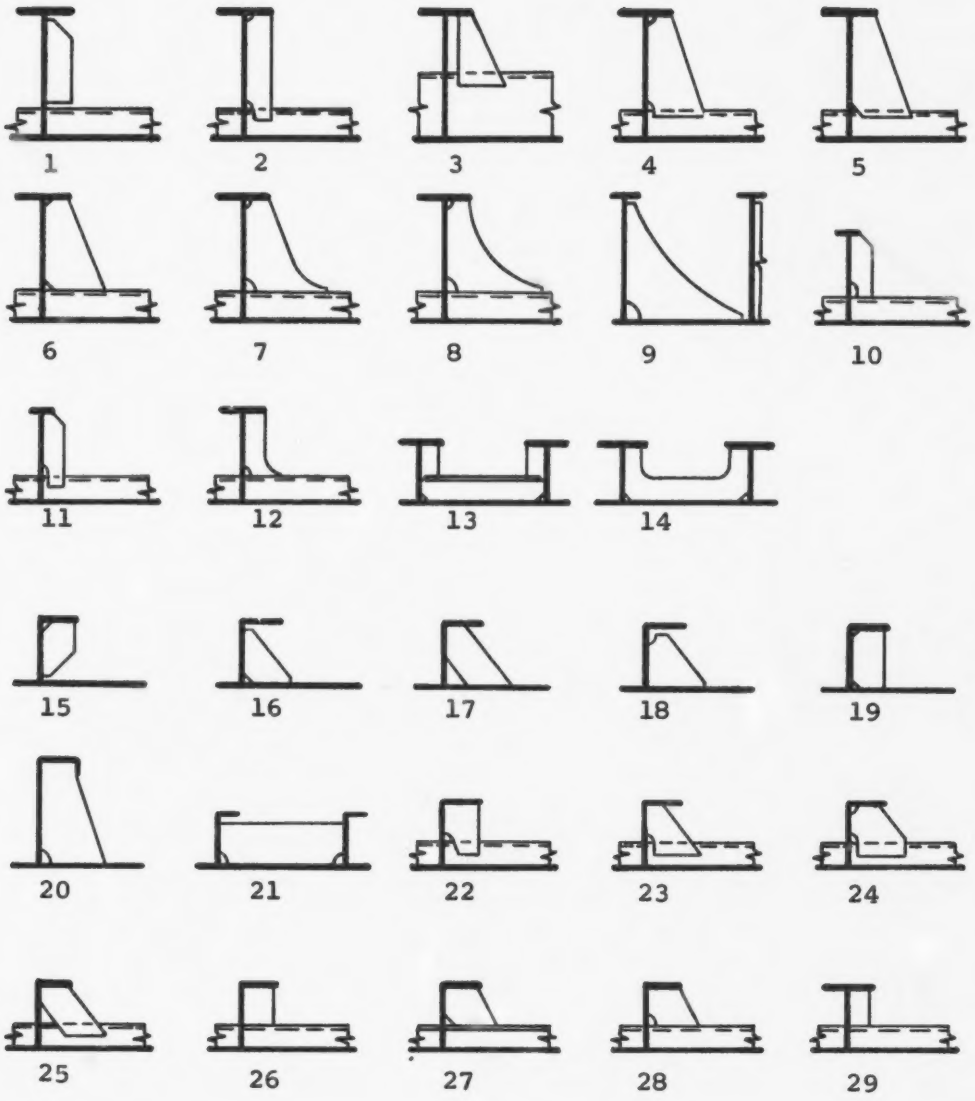

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FIGURE 9 - TRIPPING BRACKET DETAILS, Family No. 2 (Cont'd)

B.

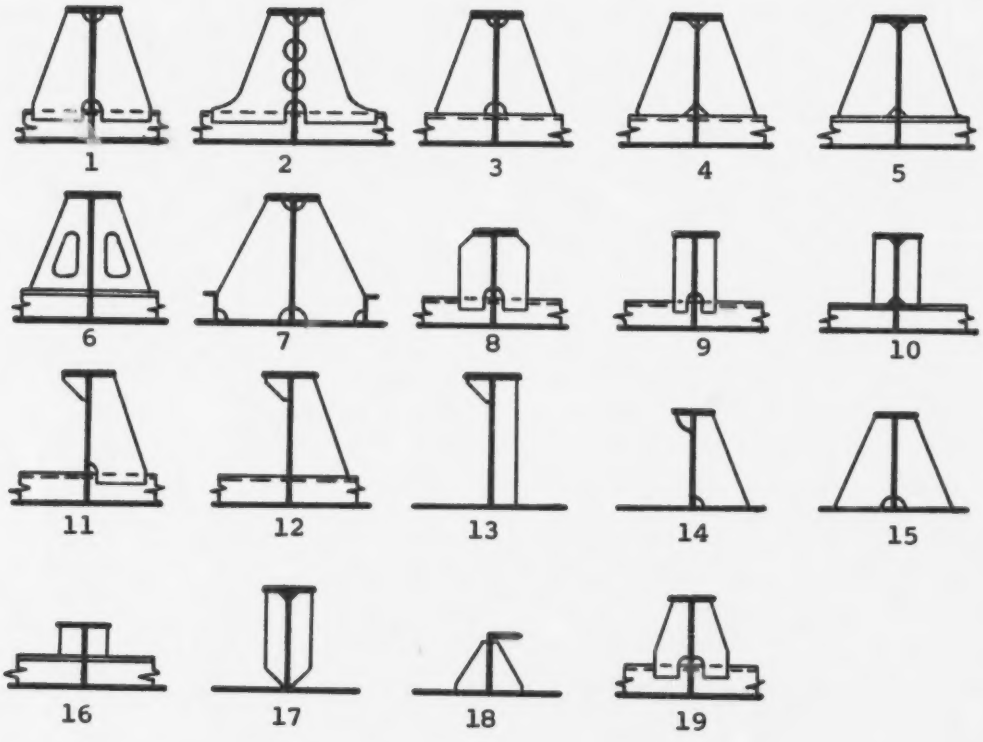

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FIGURE 9 - TRIPPING BRACKET DETAILS, Family No. 2 (Cont'd)

c.

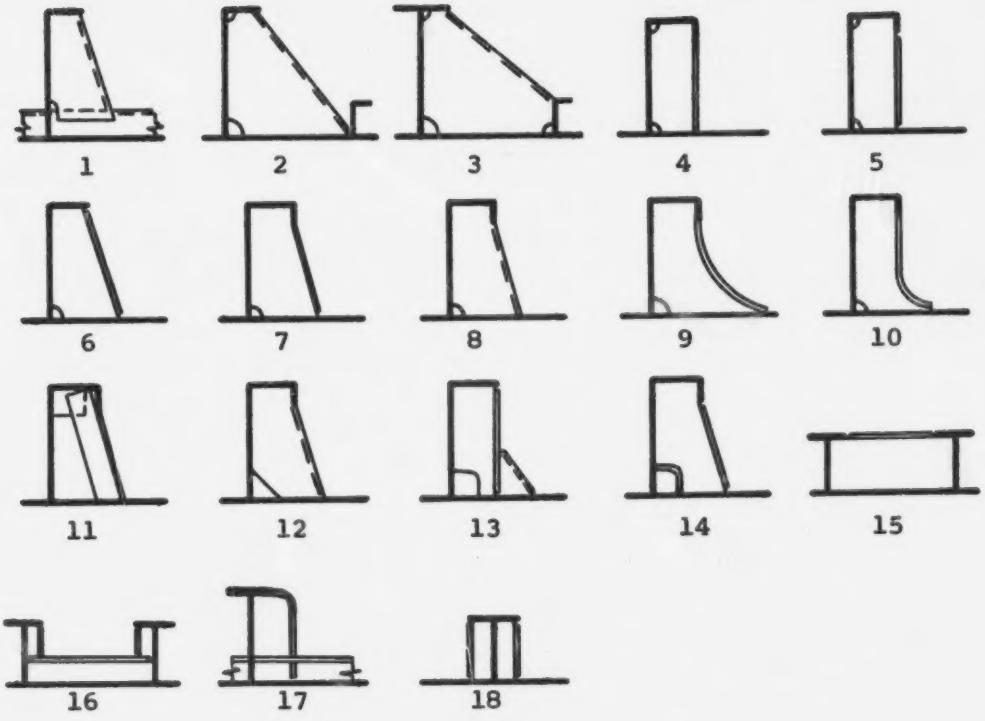

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TABLE 5

SUMMARY OF TRIPPING BRACKETS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	Sound Details	% Sound Details	Number of Details	Number of Failures	% Failures
A	10240	10179	99.4	22470	72	.3
B	6920	6865	99.2	15210	68	.4
C	3480	3282	94.3	7540	218	2.9
TOTAL	20640	20326	98.5	45220	358	.8

BEST DOCUMENT AVAILABLE

undercut welds at the bracket toe edges. The combined conditions resulted in cracks developing in the heat affected zone.

Conclusions drawn from groups "A" and "B" in Table 5 indicate that tripping brackets are not necessary on both sides of the web. Results for individual details support this conclusion. For instance, detail 2-A-4 has one lateral supporting bracket whereas detail 2-B-1 has identical brackets on each side of the web. Neither detail failed. Failures occurred in both details 2-A-6 and 2-B-12 which are identical except for the chock on the opposite side of the web in detail 2-B-12. This further strengthens the position that tripping brackets are needed on one side only of a girder subject to in-plane loading and can also be designed to be effective in the support of a girder subject to lateral loading.

Twenty percent of the tripping bracket failures were in the buckling mode due to collisions, corrosion, heavy weather, and design in descending order of cited frequency. Most of these failures occurred forward of amidship which suggest that details in the forward end of the ship which are subject to seawater loading should be given special attention.

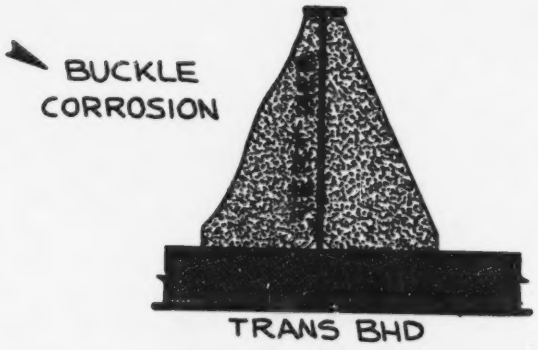
In several of the interviews ship officers stated that the ships had to slow down in heavy weather; that the actual speed is a matter of judgment with consideration for the safety of the crew, cargo and ship; and that a trade-off occurs between repair items and meeting cargo delivery schedules. Usually the ship was slowed down just enough for safety but not enough to prevent minor structural damage. This damage was most noticeable at the bow on forecastle decks and in structure attached to the forward side shell plating.

Five samples of failed tripping brackets are shown in Figure 10. Shown are one case of a buckled bracket and four cases of cracks at bracket toes. Detail 200 was buckled primarily as a result of severe corrosion of the flat plate bracket which lowered its critical buckling stress level. Detail 201 had a crack that started at the toe of the bracket and extended in one direction through the shell longitudinal's flange and in the other direction into the longitudinal's web and near the shell plating. Cracks at the toes of detail 202, 203, and 204 were in the heat affected zone of the weld and in detail 204 the crack had extended into the flexing bulkhead plating which resulted in a noticeable oil leak between the two compartments.

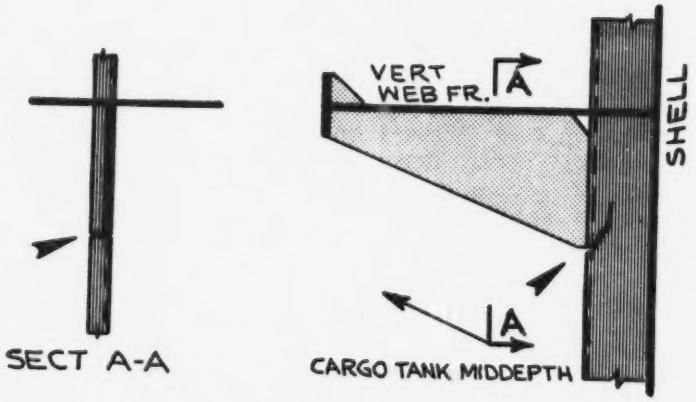
Figures 11, 12, and 13 are photocopies of failed tripping brackets on a containership, general cargo ship and a tanker. A weld build-up was added at the bracket toe of Figure 11 in an historical attempt to prevent further cracks which later occurred as shown. Figure 12 shows a tripping bracket that received impact blows from presumably rough handling of containers or heavy bulk items. Other structure within the cargo area of the ship had a similar extensive damage appearance. Figure 13 shows a buckled flat plate bracket that supported a deck-house bulwark on a tanker. This apparent impact damage also included a crack at the cutout in the deck-bulwark corner. Failed brackets were also present in the cargo oil tanks but their photographs were not reproducible.

FIGURE 10

SAMPLE TRIPPING BRACKET FAILURES



DET 200
TANKER



LONGL. AT A WEB FRAME

DET 201
TANKER

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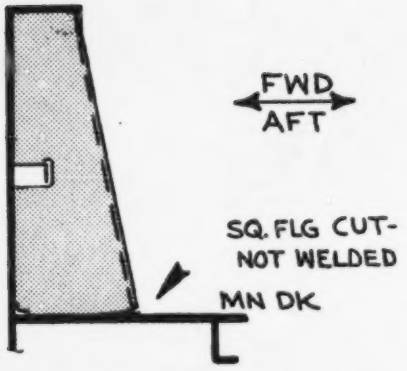
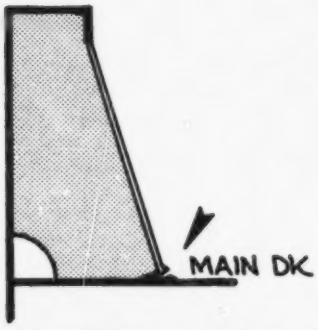
FIGURE 10 - SAMPLE TRIPPING BRACKET FAILURES (Cont'd)



CARGO HATCH COAMING

DET 202

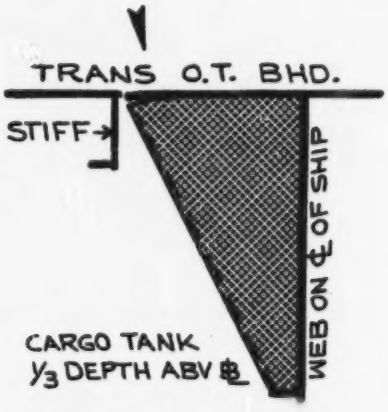
ORE CARRIER



BKT ON HATCH END BEAM

DET 203

CONTAINERSHIP



PLAN VIEW SECTION

DET 204

TANKER

BEST DOCUMENT AVAILABLE

FIGURE 11

FAILED TRIPPING BRACKET AT A HATCH END ON A CONTAINERSHIP

This flanged plate tripping bracket supports a transverse hatch coaming on main deck. The picture is of the bracket toe at main deck where layers of welds have been added in an attempt to distribute the load in the deck plate over a larger area. A short crack exists in the bracket immediately above the weld layers.

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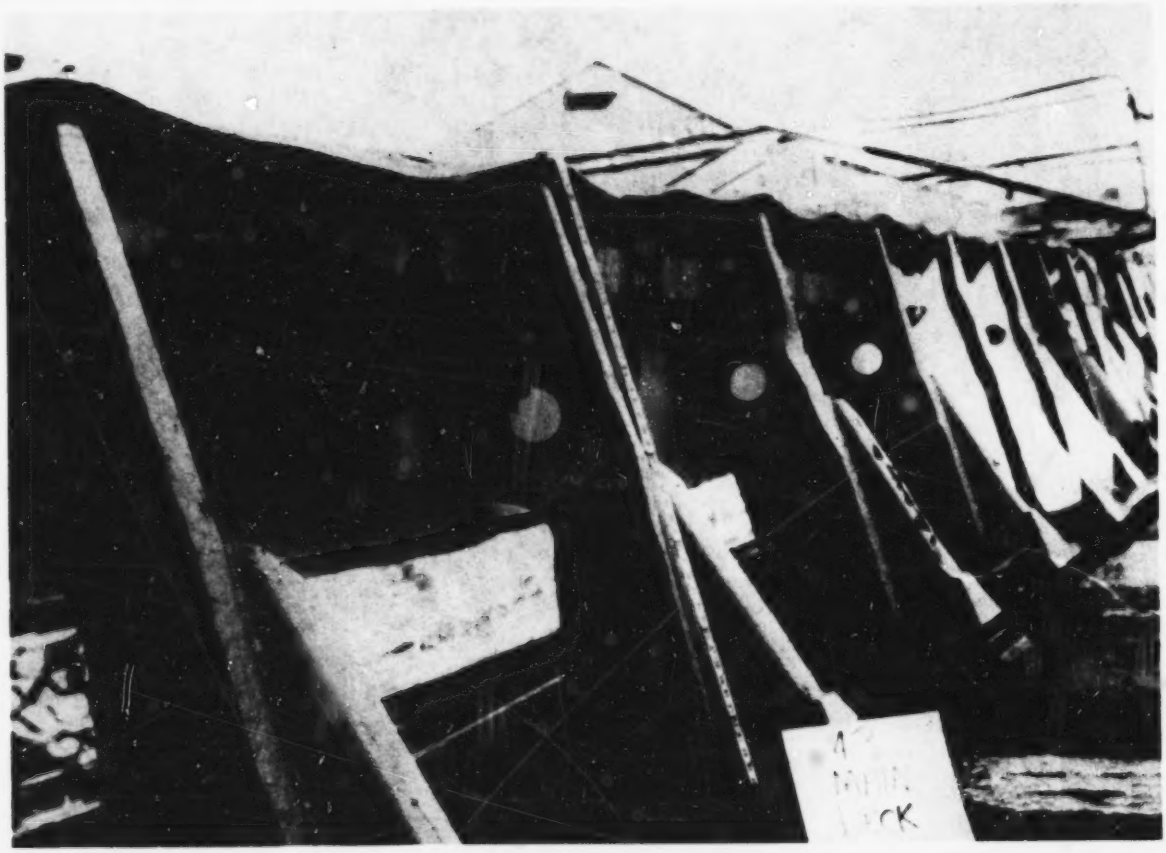
FIGURE 12

FAILED TRIPPING BRACKETS SUPPORTING
THE BULWARK AT THE SHELL ON A GENERAL CARGO SHIP



The photograph is on starboard side looking outboard and aft. In addition to the obvious battered coaming and flanges, cracks exist in diverse places in the brackets at the connections.

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FIGURE 13

FAILED TRIPPING BRACKET SUPPORTING
A DECK-HOUSE BULWARK ON A TANKER

The bulwark is on the forward side of a deck-house. The buckle in the bracket is due to an impact load on the bulwark. A crack also exists at the corner weld clearance cutout where the bottom of the bracket connects to the bulwark and to the deck.

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In summary, design of tripping brackets on transverse hatch ends should be carefully considered especially on ships where three tiers of containers on the cargo hatches are expected; tripping brackets need not be on both sides of an in-plane loaded web; and landings of tripping brackets should be on relative strong stiffeners or on deck locations directly above backup structure. Ship operators can expect structural failures when the ship is "driven" through stormy seas.

FAMILY NUMBER 3 - NON-TIGHT COLLARS

Thirty-six variations of non-tight collars were observed in thirty-four of the fifty ships surveyed with failures occurring in only five ships. The remaining sixteen ships had no non-tight collars. The thirty-six variations were separated into three general groups in Figure 14 based on the method of attachment used to connect it to the through members. Group "A" has one connection to the through members; group "B" has two connections to the through members; and group "C" has three connections to the through members. Results for each group is summarized in Table 6.

A very high percent (99.9%) of the details were sound. The remaining .1% is an estimated thirty-three failures as presented in Table 7 which gives the distribution according to ship types, location within the ships, and reasons for the failure of the details. They were in three different forms as shown in Figure 15 where cracks existed at the intersection of the collar clips and the cutouts in two cases and where distortions were present in the web plating and collar clip in the other case. Detail 300 could reasonably be considered a failure of the web frame plating rather than the collar.

Form 3 in group "B" (detail 3-B-3 in Figure 14) appeared to be a historical repair item since the clips were on bottom transverse web frames at longitudinals where shell framing deflections are expected to be large during heavy weather. This clip method or a modified one can reasonably be expected to alleviate the crack problem around the cutouts. A suggested modification is to add a radius in the clip at the resulting cutout corner nearest the free end side of the stiffener flange.

In summary, the physical integrity of the non-tight collars was very high over the full survey range and a meaningful percentage of the sparse failures could be attributed to adjacent web plating panel buckles. One clip method for alleviating cracks around cutouts appears reasonable.

FAMILY NUMBER 4 - TIGHT COLLARS

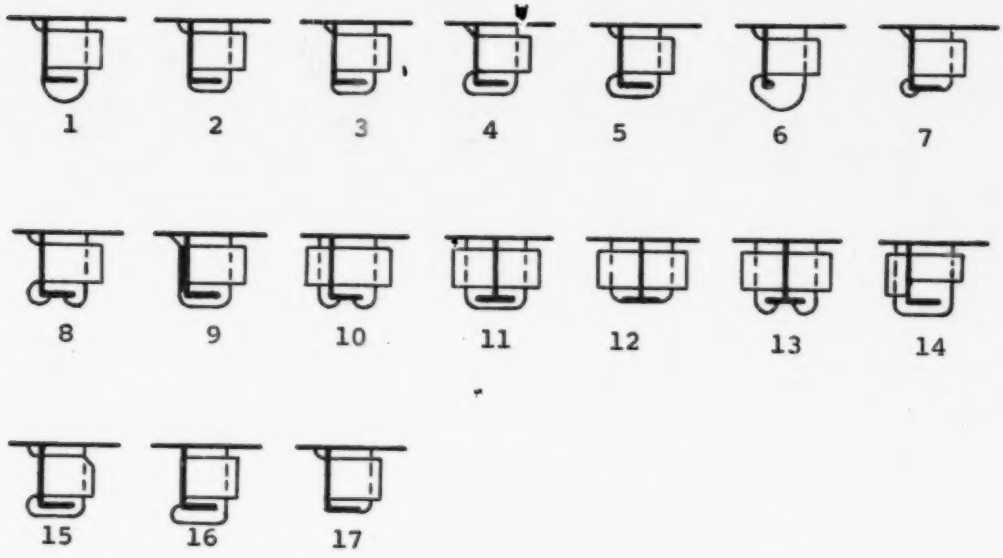
All observed tight collars were sound. Figure 16 shows the thirty-two configurations in the four family groups as reported in the data of Table 8. Note that group "D" contains slots which accommodate through members and are considered as "tight collars" in this report.

Singular collar forms were assumed to be adapted to the type of vessel service and the construction techniques used in the building

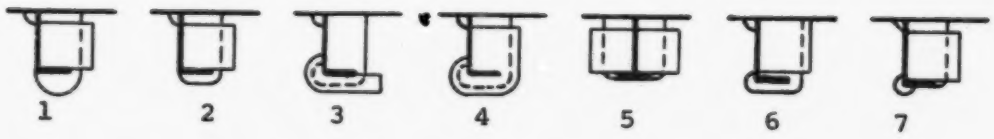
FIGURE 14

NON-TIGHT COLLAR DETAILS
FAMILY NO. 3

A.



B.



C.

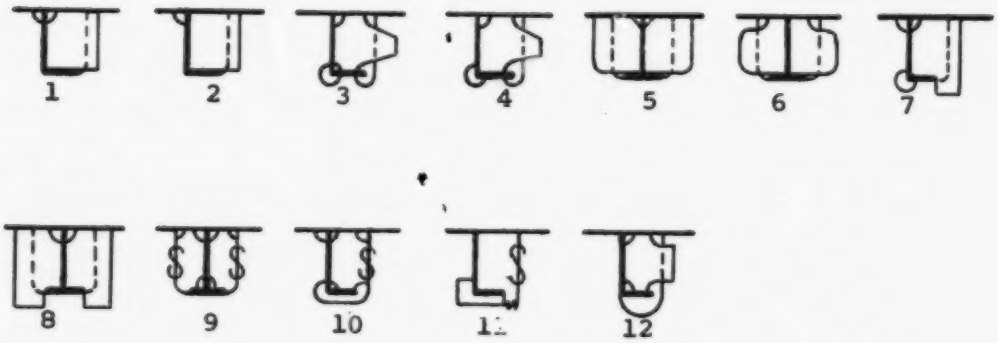


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TABLE 6

SUMMARY OF NON-TIGHT COLLARS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failure Details	% Failures
A	6550	6539	99.8	14770	13	.1
B	5700	5700	100.0	11850	-	-
C	4000	3983	99.6	11420	20	.2
TOTAL	16250	16222	99.8	38040	33	.1

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TABLE 7

DISTRIBUTION OF FAILED NON-TIGHT COLLARS

Ship Type	Number of Failures	Location Along Ship Length	Failure Cause
Bulk Carriers	10	Aft	Questionable
Containerships	4	2 aft, 2 amidship	Fabrication/ workmanship
General Cargo	10	Aft	Fabrication/ workmanship
Miscellaneous	3	Forward	Collision
Tankers	6	Forward	Collision

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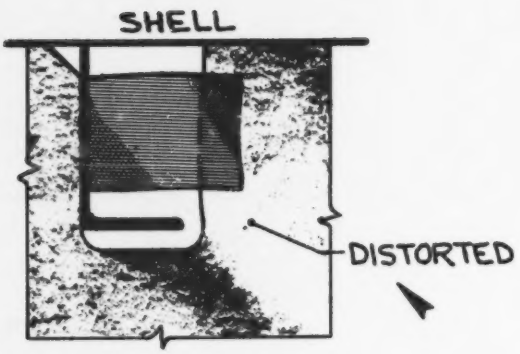
FIGURE 15

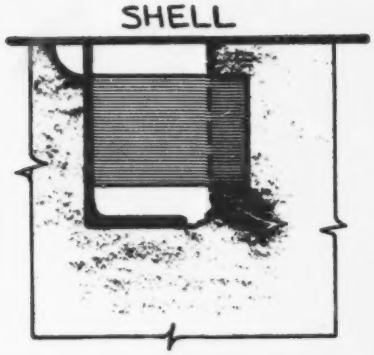
SAMPLE NON-TIGHT COLLAR FAILURES



WEB FRAME - BOW

DET 300

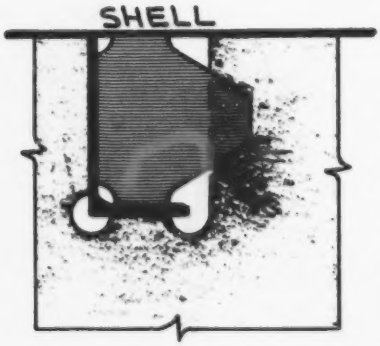
TANKER



SHELL FRAME ℄

DET 301

CONTAINERSHIP



WEB FRAME - AFT

DET 302

BULK CARRIER

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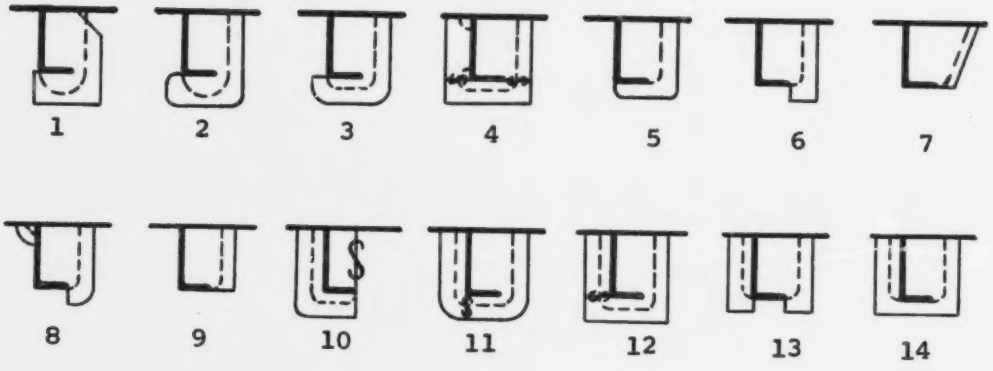
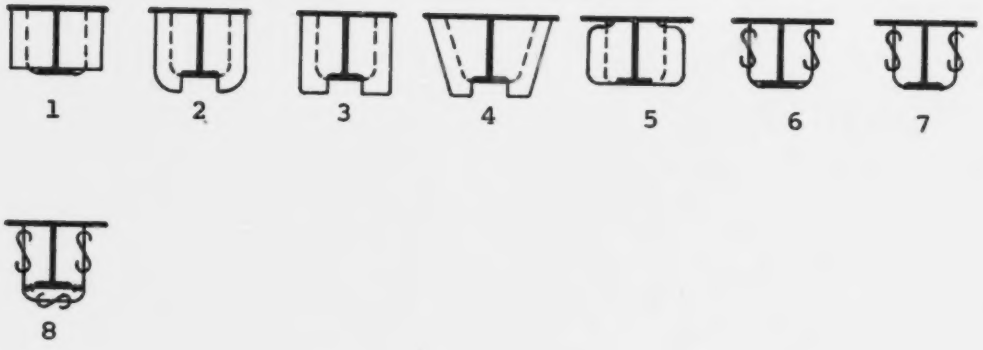
FIGURE 16

TIGHT COLLAR DETAILS
FAMILY NO. 4

A.



B.



C.

D.

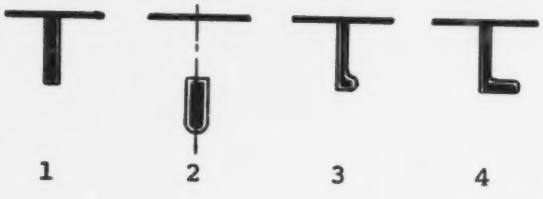


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TABLE 8

SUMMARY OF TIGHT COLLARS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	7220	7220	100	19740	0	0
B	3770	3770		16620		
C	740	740		2100		
D	6270	6270		17300		
TOTAL	18000	18000	100	55760	0	0

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yards. Collars such as detail 4-A-11 cover cutouts that have both horizontal and vertical clearances around the through angle. Collars such as detail 4-B-3 enclose cutouts which have only horizontal clearances, and those such as detail 4-D-1 have very little horizontal and vertical clearances. The majority of the collar lugs were lapped onto the plating around the clearance cutouts. Frequent areas of rough welds and weld splatters on transverse bulkhead plating were found around the collars in the merchant ships but did not result in any collar or adjacent structure failures.

In summary, the inspection results show that all the tight collars in the survey were functional and undamaged.

FAMILY NUMBER 5 - GUNWALE CONNECTION

Throughout the history of ship design and construction, particular emphasis has been placed on the connection of the side shell to the strength deck in an effort to eliminate the possibility of a crack propogation that could result in such a catastrophic structural failure that the ship would be ultimately lost. This gunwale connection has been accomplished by either riveting or welding and of the twenty gunwale connections observed, twelve were of riveted construction and eight of welded construction. They are shown as two groups in Figure 17 with data summarized in Table 9.

Workmanship in the examined gunwale connections was excellent except in one or two places on a few ships where minor variances would be present in a weld overlap. In one gunwale detail, a liner was in the riveted connection between the shear strake and the deck flat bar as shown in detail 5-A-9 of Figure 17.

Two ships had several local out-of-plane displacements above main deck in the vertically cantilevered portion of the shear strakes on both sides of the ships. Probable causes for the out-of-plane areas are excessive compressive stresses in the gunwale, lateral forces applied by wire ropes, or collisions with horizontal objects at piers. In every occurence, however, plate displacements were inboard. Photographic records of the weakened gunwales include those in Figures 18 and 19.

One interesting aspect about the "B" group is the amount of roundness at the top edge or corner. Excluding detail 5-B-1, the sharpness of the shear strake's top outboard edge ranges from square in detail 5-B-5 and 5-B-8 to a full radius in detail 5-B-7. Detail 5-B-4 had a 5 mm radius as specified on the ship's copy of the midship section plan.

Deterioration by corrosion of the gunwale details was evident on the older commercial ships but was not present on the naval vessels. Group "A", the riveted connections, contained corroded areas where the rivets had loosened during service; no rivets were missing. Other weakened effects such as notch cuts, drainage holes or abrasions were not seen in any of the connections.

The inspection results given in Table 9 contain numbers related to the sound and failed details. Totals should be interpreted by

FIGURE 17

GUNWALE CONNECTION DETAILS
FAMILY NO. 5

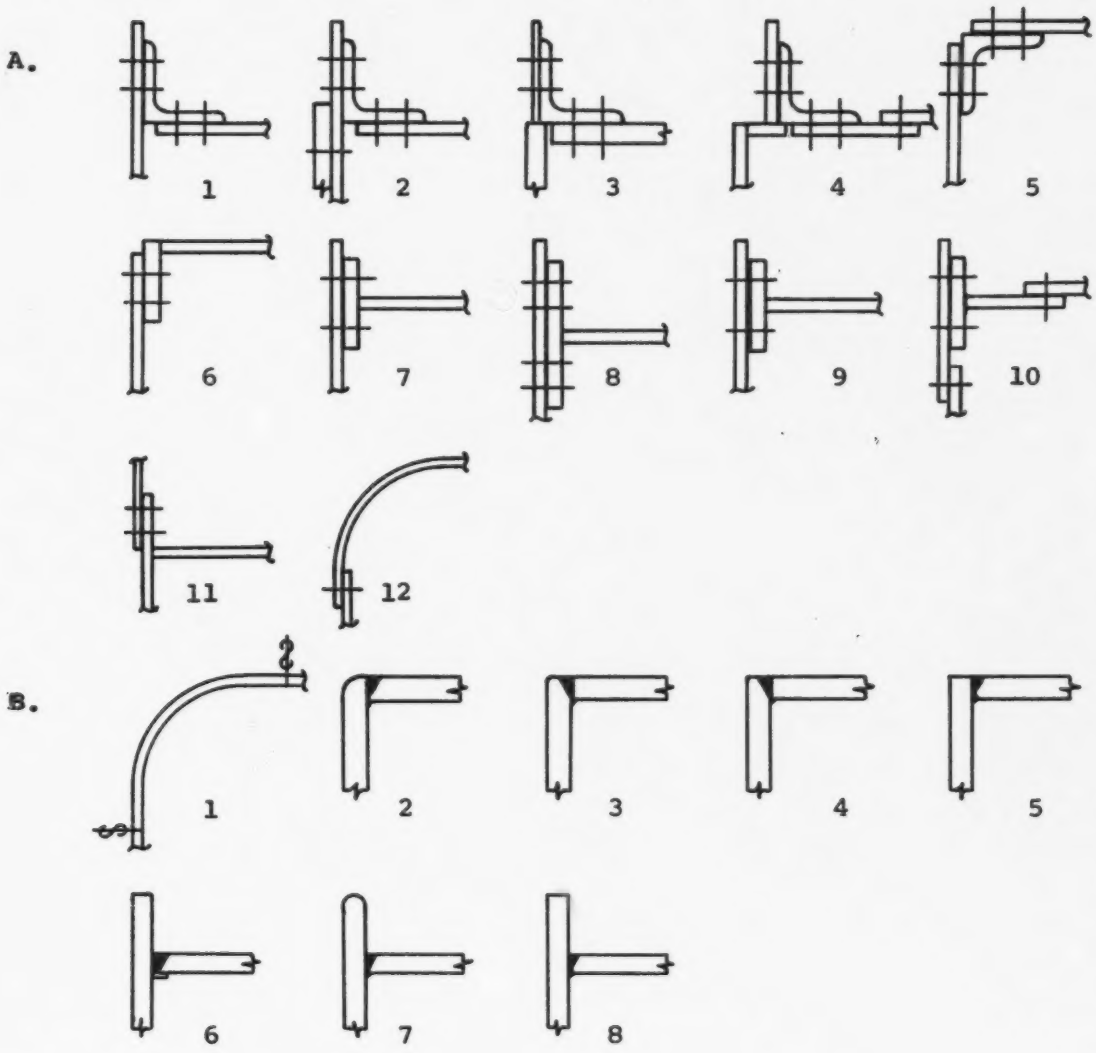

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TABLE 9

SUMMARY OF GUNWALE CONNECTIONS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	58	56	96.5	58	2	3.4
B	42	40	95.2	42	2	4.8
TOTAL	100	96	96.0	100	4	4.0

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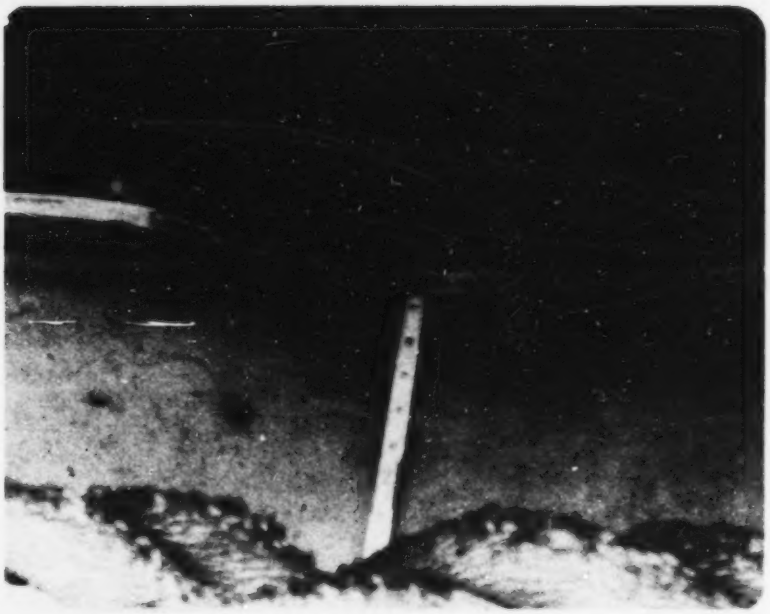
FIGURE 18

FAILED GUNWALE CONNECTION
ON A MISCELLANEOUS VESSEL



Photographer is standing on main deck looking down at the gunwale. These out-of-plane displacements occurred in several places along the length of the gunwale on both sides of the vessel. Cracks were not observed in the detail which is similar to 5-B-8. The upper part of the picture shows part of a rope above the ruler.

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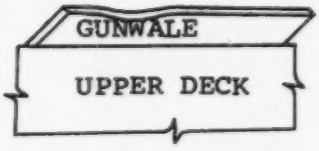
FIGURE 19

FAILED GUNWALE CONNECTION ON A TANKER

KEY TO PHOTO



The inward displacements of one to two inches (as indicated by the folding rule) in the shear strake extension were present at several midship and forward locations on both sides of the ship. The gunwale connection is similar to detail 5-A-7.

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realization that each ship contains only two gunwale details - one on each side of the ship. Only one failure is given in the table for each failed gunwale although several places along the gunwale length may have been defective. If the percent failure were considered as the failed segment lengths relative to the total length of all the gunwales, the calculated percentage would be too small to reveal the gunwale faults. As presented in the table, the defective bends in the four gunwales become significant.

In summary, two ships had visible bent places along the length of their gunwale connections. These were suspected, but unverified, to be due to exterior abuse rather than to internal stresses from expected ship operations. Workmanship in these details was excellent.

FAMILY NUMBER 6 - KNIFE EDGES

Knife edges were not found on any of the fifty ships. This does not eliminate the existence of knife edges since they are almost certain to occur in the design and alterations of complex ship structure. The problem is to locate them on the ship. To detect a definite "knife" requires a study of the detail structural plans used in the construction of the ship and in all subsequent structural modifications. This would be extremely time consuming as well as impossible for a study of this type since the ships do not carry these drawings with them.

It would normally be expected that most cracks due to knife edges show up very early in a ship's life, however, the survey interviews did not totally confirm this. Statements regarding repairs involving knife edges crossings were relevant to vessels not included in the survey. In those vessels most knife edge problems were allegedly at the terminations of platform decks and bulkheads in and around miscellaneous tanks, machinery spaces and deck-houses.

FAMILY NUMBER 7 - MISCELLANEOUS CUTOUTS

Functional groups in the miscellaneous cutout family are access openings, air escapes, drain holes, lapped web openings, lightening holes, pipeways, wireways, and weld clearances. Sketches of the miscellaneous details are presented in the eight groups of Figure 20. The family was deliberately limited to these cases in order to omit data on unique one-of-a-kind geometrys.

Each individual detail is placed in only one group according to the detail's major function irregardless of the number of duties it may fulfill on the ship. A few details look alike such as 7-A-1, 7-C-13, and 7-E-1, but the primary function is different from group to group. For instance, detail 7-A-1 has a primary function to provide access and could in some places have a secondary function as a drain hole and air escape. Detail 7-C-13 has a primary function to provide drainage but could also act as an emergency access, a lightening hole, and an air escape. Thus, because the primary function changes, the circular cutout is placed in two or more groups.

FIGURE 20

MISCELLANEOUS CUTOUT DETAILS
FAMILY NO. 7

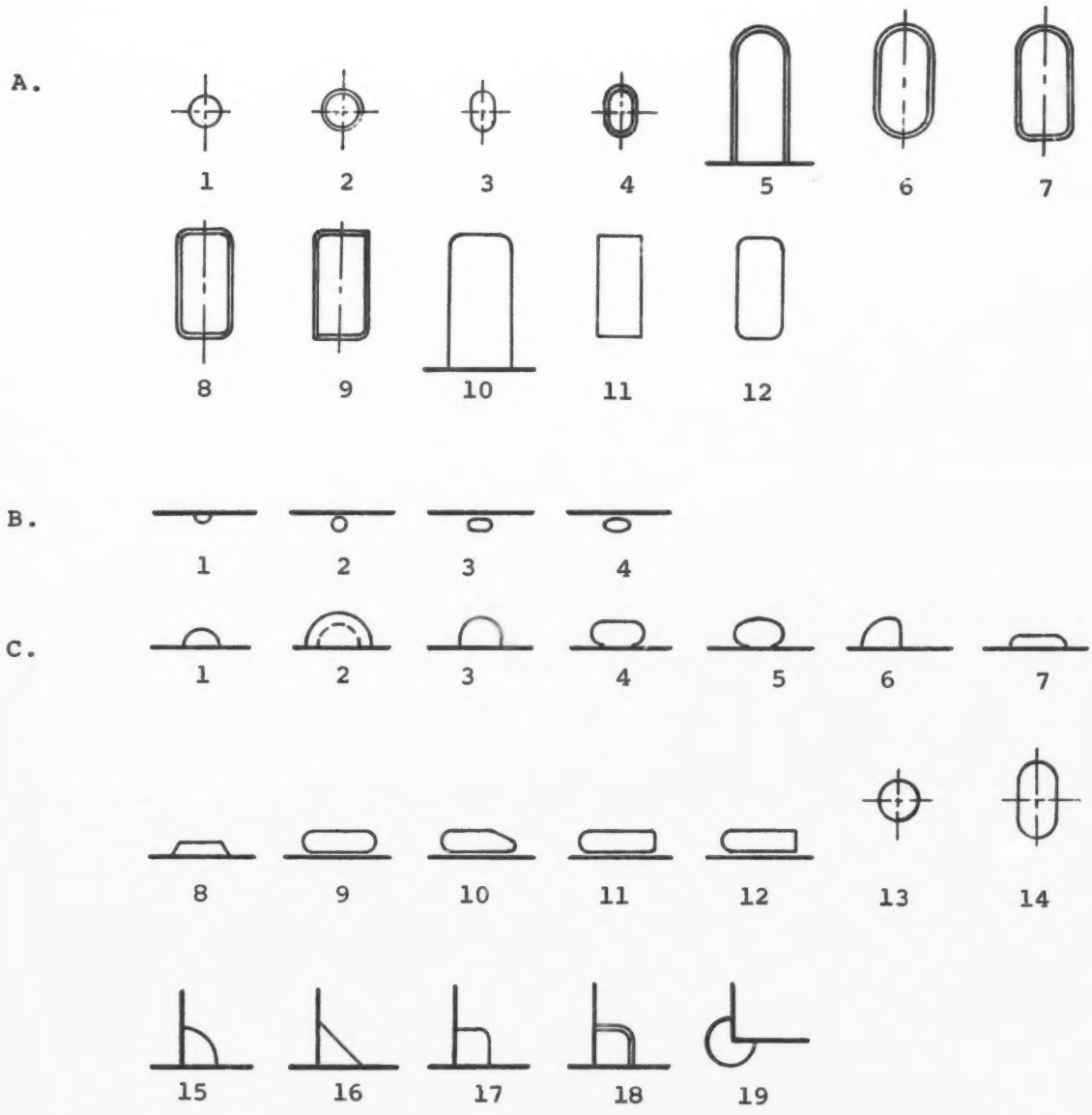

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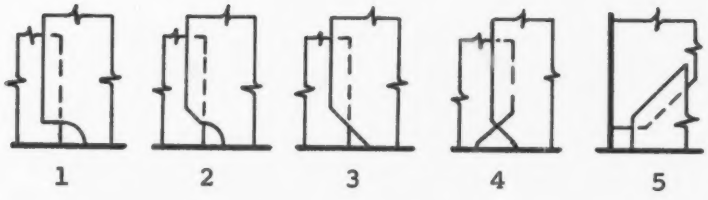
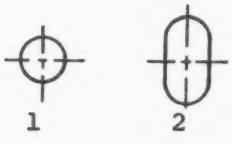
FIGURE 20 - MISCELLANEOUS CUTOUT DETAILS, Family No. 7 (Cont'd)

D.



E.



F.

G.

H.

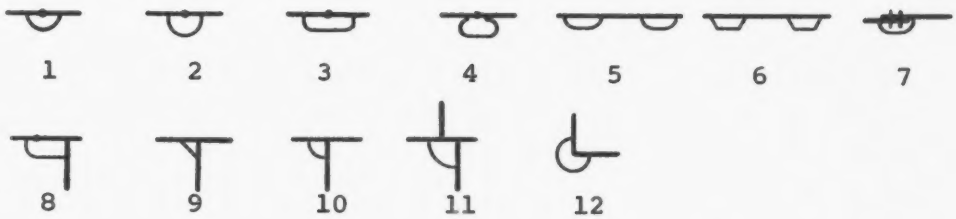


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Table 10 contains the component numerical results. The wireways had the highest percent of sound details, whereas the lapped web openings and the lightening holes had the highest failure percentage. Totals for the entire family show a high percentage of sound details; however, since the family contains numerous details, failures averaged 14-1/2 per ship which is the third most prevalent within the twelve families. This can be seen in the report summary in Table 16, "Summary of Data from Fifty Ships".

The access openings in group "A" had failures in details 7-A-6, 7-A-8, 7-A-9, and 7-A-11. Except for detail 7-A-11, these were mostly cracks in steel and aluminum bulkhead plating at two diagonal corners of each forward doorway inserted in the main deck-house longitudinal enclosure bulkheads immediately above the main deck. Detail 7-A-11 appeared in miscellaneous steel bulkheads where cracks originated at the square corners.

Openings in any beam like structure that develops both shear and bending stresses require additional consideration in both design and fabrication. The longitudinal box girders on a containership are this type of structure. It was evident on the containerships surveyed that weld repairs had been made to prior cracks adjacent to openings in the box girders. A possible damaging crack was also observed in the bulkhead plating at the corner of an access opening in one of the box girders (Figure 21). The crack apparently originated in the weld and propagated a few inches into the adjacent bulkhead plating. Workmanship in and around the detail appeared very good. Corrosion did not appear to be a problem. The crack location and the detail structural setting suggests the presence of both excessive secondary bending stresses combined with primary bending stresses and the presence of a possible weld defect at the start of a new weld layer. These secondary bending stresses are produced by the resulting shear in the beam or girder and are usually cyclic in nature due to varying loading conditions and constantly changing environment. The primary stresses in the structural beam or girder may be acceptably below the fatigue limit even with an opening added, but, the secondary bending stress, when combined with the primary stress, may produce stress levels above the fatigue limit. These unpredicted stress levels reduce the member's fatigue life. Eventually a loading condition, which may have occurred in the past, produces stresses which result in crack development and propagation. In all designs, a prudent arrangement of structural openings should be selected and secondary stress analyses performed. This could eliminate costly repairs that occur following delivery. Figure 22 is a picture of another opening aft of the one in Figure 21. This after opening has a smaller face plate with intermittent weld. A vertical weld repair is visable at the top of the arch.

Air holes were relatively free from defects except on containerships and naval vessels where the failures were due to heavy seas and corrosion in inaccessible or nearly inaccessible locations, respectively. Structure behind wireways and vent trunks was frequently susceptible to corrosion from neglect. One tanker operator suggested minimizing the number of air holes to reduce coating costs.

TABLE 10

SUMMARY OF MISCELLANEOUS CUTOUTS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	3850	3822	99.3	11120	29	.3
B	16810	16782	99.8	42700	40	.1
C	49980	49894	99.8	112130	99	.1
D	2190	2171	99.1	4390	24	.5
E	17510	17351	99.1	44370	221	.5
F	4010	4000	99.8	10420	12	.1
G	9900	9895	99.9	28240	5	.0
H	148620	148309	99.8	536340	364	.1
TOTAL	252870	252224	99.7	789710	794	.1

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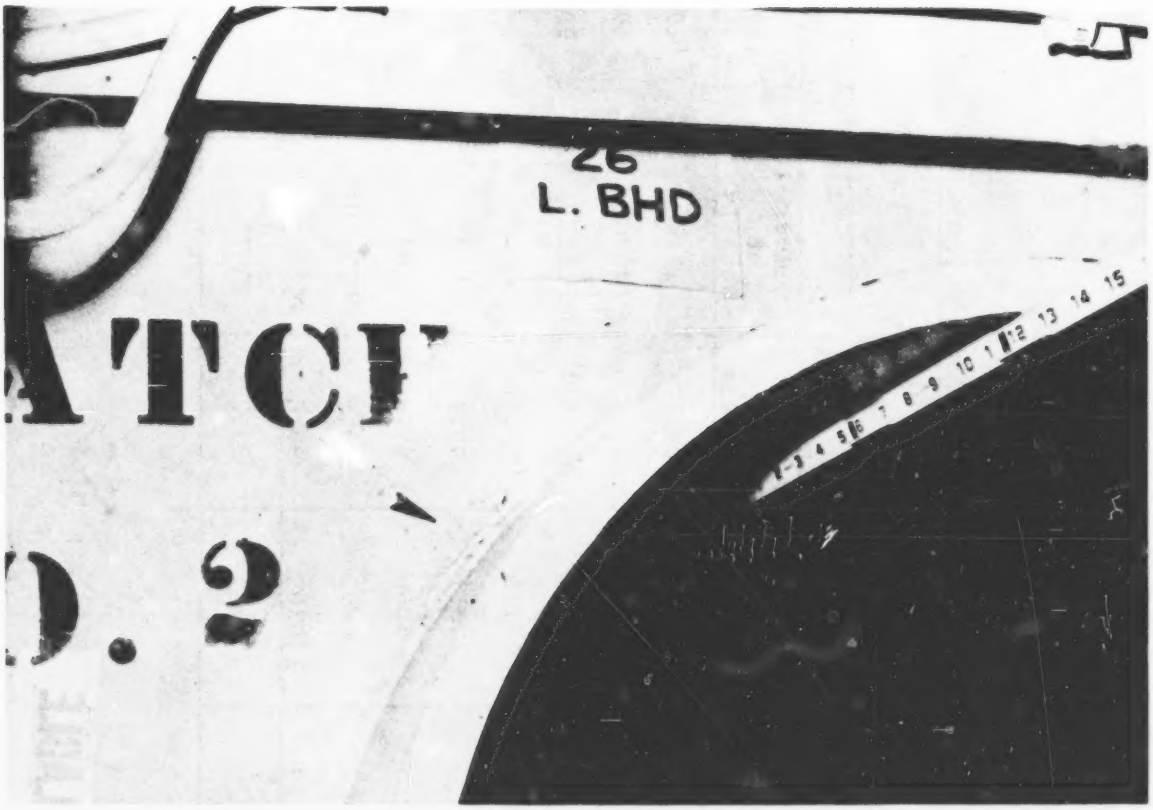
FIGURE 21

DEFECT AT AN ACCESS OPENING
IN A CONTAINERSHIP



The access opening similar to detail 7-A-6, is near the forward end of the cargo space and in the longitudinal bulkhead of the box girder. The defect is a four inch crack in the weld of the coaming to the bulkhead plating. This detail has a history of repairs - see text.

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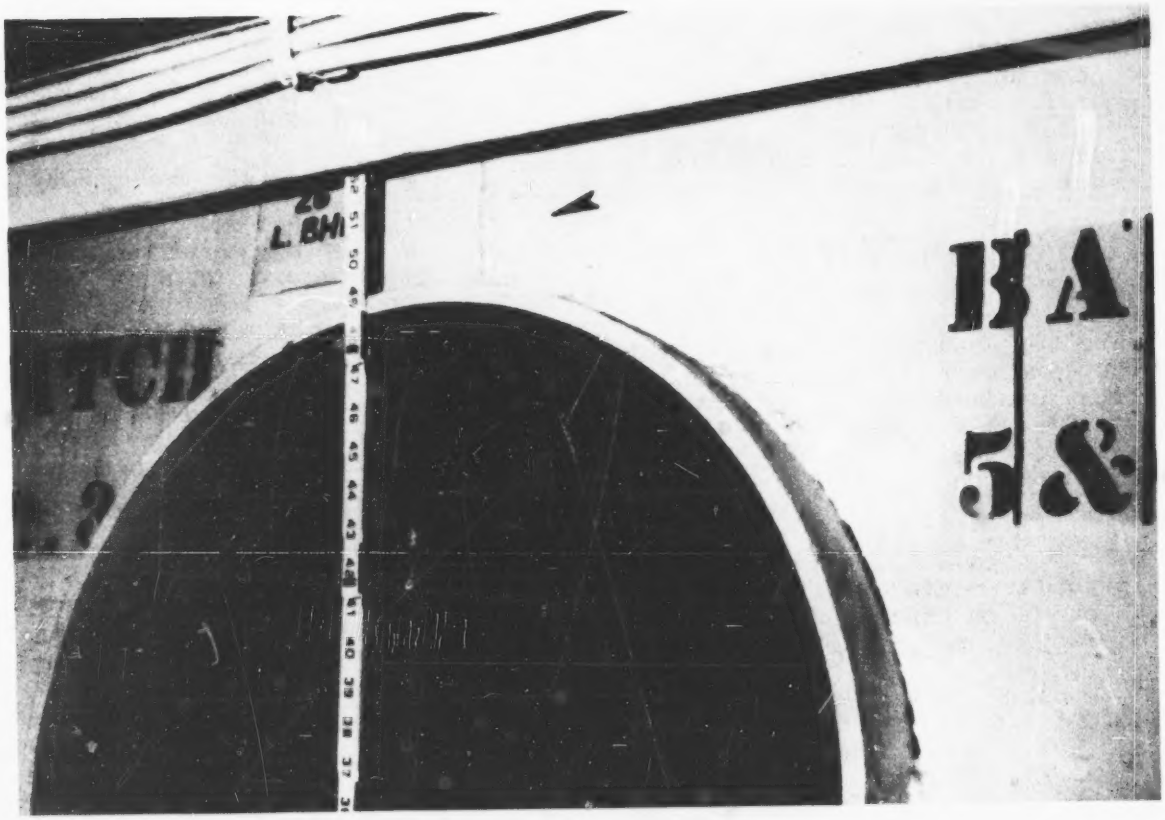
FIGURE 22

HISTORICAL DEFECT AT AN ACCESS OPENING IN A CONTAINERSHIP



The access opening is in the same box girder as the opening in Figure 21. Similar to detail 7-A-6, this opening has intermittent welds connecting the face plate to the longitudinal bulkhead of the box girder. The face plate is smaller than the one in Figure 21. The vertical weld centered above the opening repaired a crack that had developed in the bulkhead plating.

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Drain holes were also susceptible to corrosion in locations of poor access and neglect. Failure causes also include location in high stress regions, jagged edge cuts during construction or on board repairs, heavy sea areas in the bow, and collision. Holes in many ballast tanks, machinery spaces and shaft alleys were inadequate to properly drain water, oil, and mud from horizontal stiffeners as shown in Figure 23. A close examination of the photo in the figure shows a thick layer of mud near a drain hole in a horizontal longitudinal that has a flange extending above the web.

Reasons for failed fabrication laps were not readily apparent. Heavy weather conditions were suggested as a cause for three or four cracks at the openings. Most of the cracks, however, were due to a poor fitting, welding, eccentric forces due to the laps, and other reasons not apparent in the physical and design detail environment. A sample of a sound lap detail is shown in Figure 24 which also shows other miscellaneous cutoutsin this detail family.

Some lightening holes were in buckled web plating subjected to heavy sea loading. Some were in obvious regions of high shear and secondary bending stress. Others were the target area for cracks emanating from cutouts at web bases. Suggestions in the interviews were to eliminate lightening holes except in secondary cases where they are used for drainage and could be used for emergency access and light penetrations. Comments were that they were dangerous in horizontal structure and that metal at the edges are susceptible to rapid corrosion. Figure 25 shows a buckled web containing cracks that intersect a lightening hole. The buckle is not obvious in the picture.

Pipeways had a few failures due to defective welds, notches in irregular cut edges and poor design geometries, and improper locations relative to stress patterns in the structure. Most, but not all, pipeways were in machinery spaces and cargo tanks.

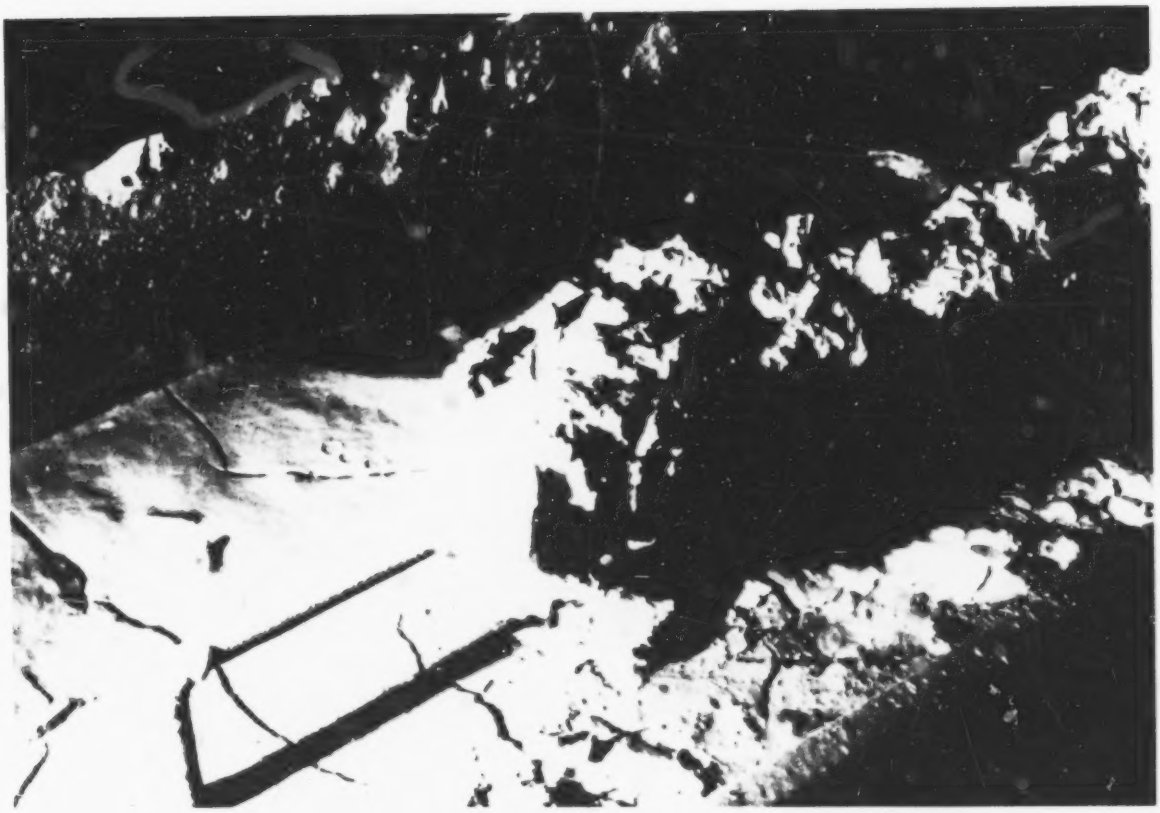
Wireways were free from failures except for five cracks in detail 7-G-3. These cracks were due to secondary bending, welding, and heavy seas. One was amidship on a containership, three were aft on a naval vessel and one was aft on a tanker.

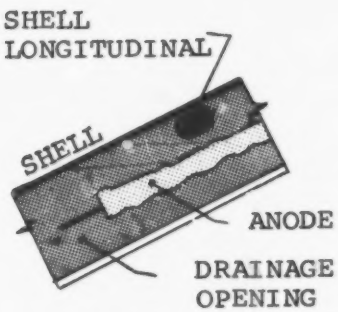
Weld clearances had more failed details than any other group in the family. Configurations 7-H-1, 7-H-5, 7-H-10, 7-H-11, 7-H-3, 7-H-12 and 7-H-7 contained the defects in numerically descending order. More cracks were observed in detail 7-H-1 than all the others combined. Elongated cracks that originated at the cutouts were the only failure modes. Numerous explanations were cited for the cracks and include design workmanship, welding, corrosion, heavy seas and collisions. Except for obvious collisions no one factor predominated as the most influential.

Figures 26 and 27 are pictures of sound and failed weld clearances. The jagged part of the sound weld clearance in Figure 26 was cut by a hand held torch during fabrication of the tanker. The cracks in Figure 27 are through the welds on a containership.

FIGURE 23

INADEQUATE DRAINAGE ON A BULK CARRIER





PLAN VIEW
KEY FOR PHOTO

The layers of mud is on the web of an upturned flanged shell longitudinal in the forepeak tank. The mud coated anode almost obscures the 3" x 6" drainage opening located behind the anode near the shell and in the 16" longitudinal. The mud is caked to within four inches of the drainage hole.

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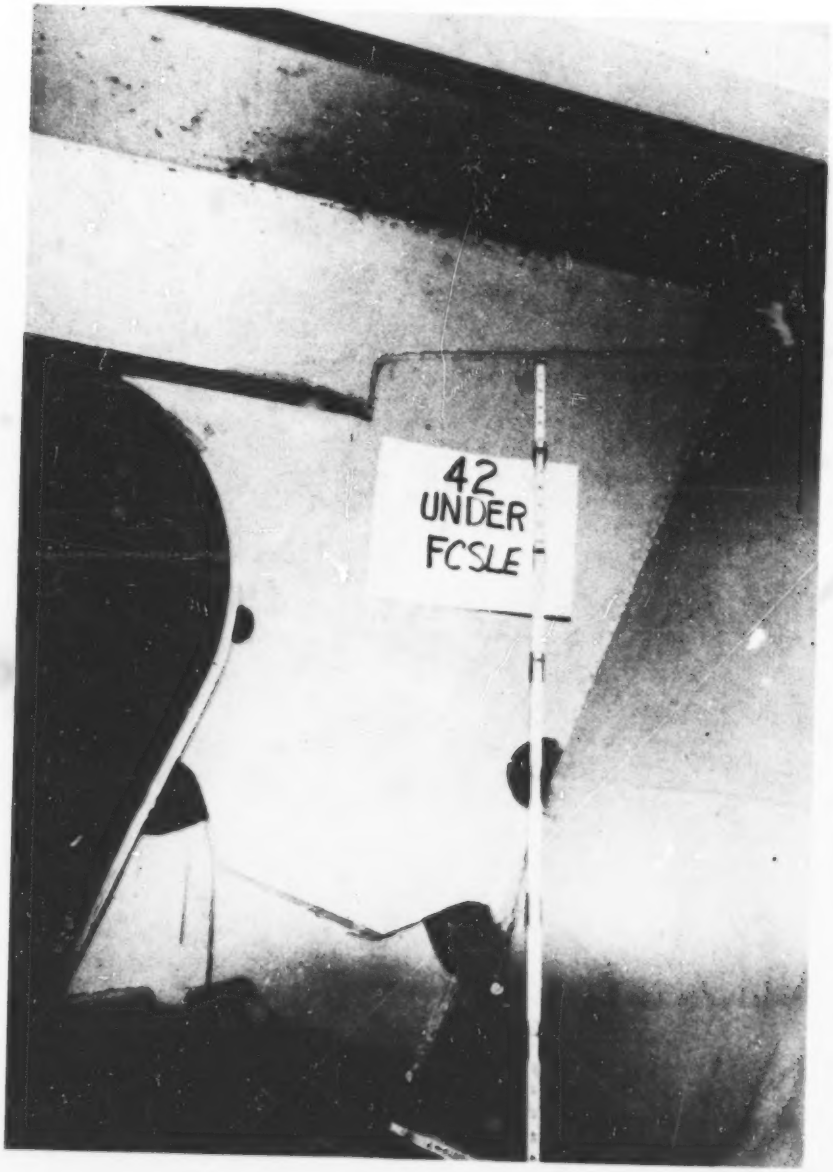
FIGURE 24

LAPPED WEB CUTOUTS AND OTHER
STRUCTURAL DETAILS IN A BULK CARRIER



This picture is of the upper portion of a web frame supporting the side shell and forecastle deck.

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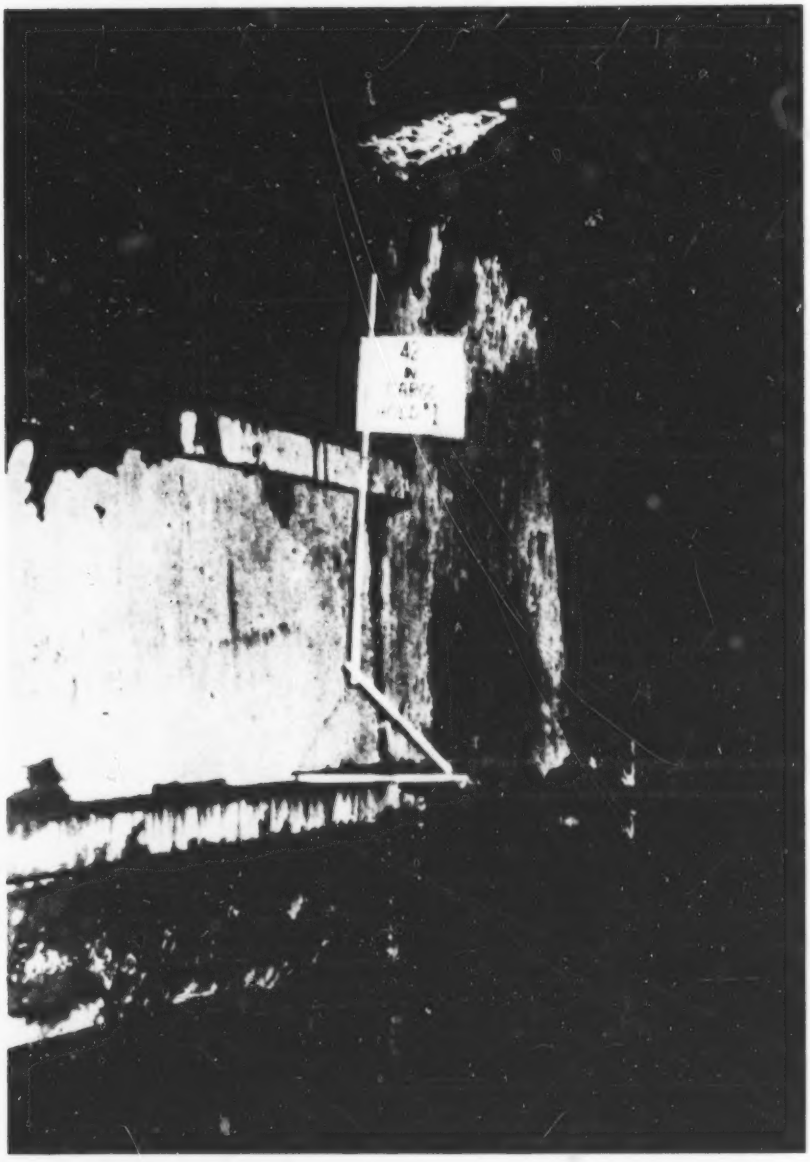
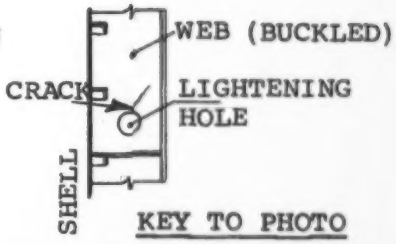
FIGURE 25

FAILED LIGHTENING HOLE IN A WEB FRAME OF A BULK CARRIER



In addition to the diagonal crack originating at the top and bottom of the center lightening hole, the panel of plating in the side shell web frame is buckled. The buckle is not apparent in the picture.

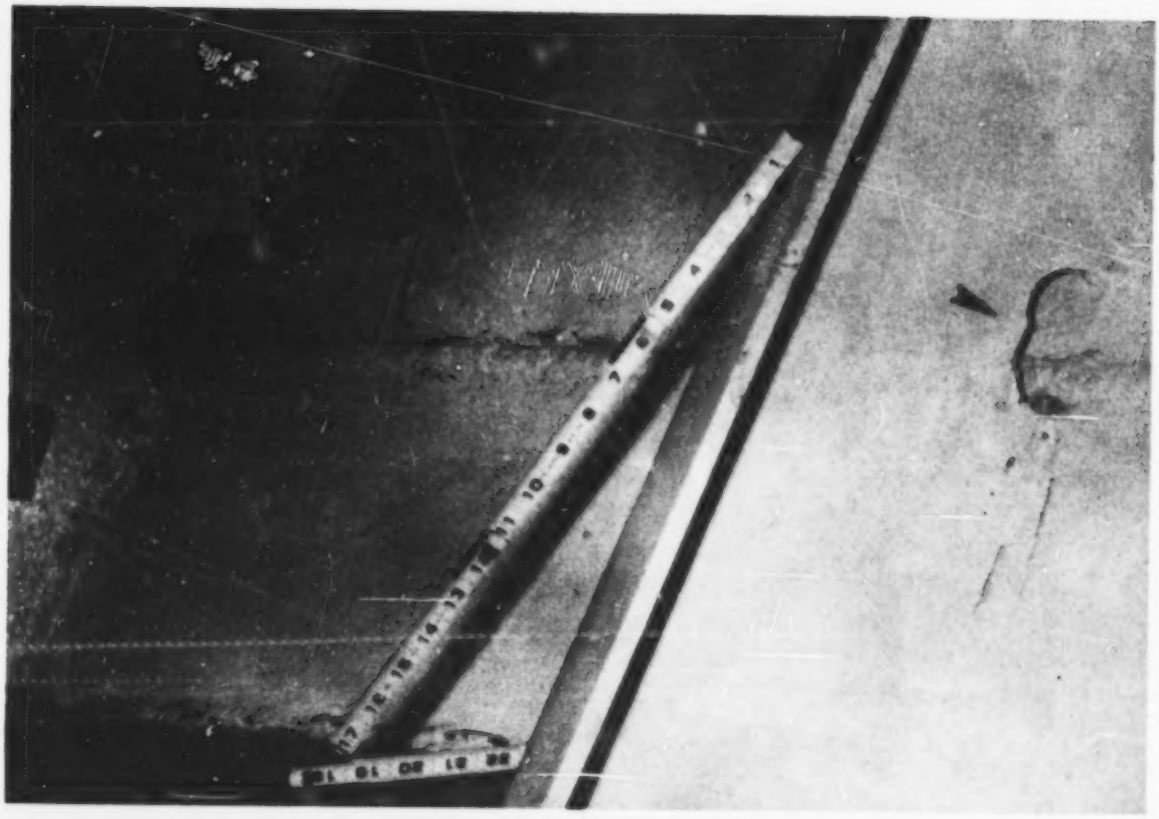


KEY TO PHOTO

BEST DOCUMENT AVAILABLE

FIGURE 26

SOUND WELD CLEARANCES ON A TANKER



The photograph shows two weld clearance cuts that were obviously elongated with a hand torch during fabrication to suit the shell seam location. These cuts were in side shell frames between forecastle and upper deck.

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FIGURE 27

FAILED WELD CLEARANCE CUT ON A CONTAINERSHIP

The crack has been rewelded above the clearance cut at the end of the folding rule. The cut is in a bracketed end of a hatch side coaming on main deck.

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Sample failures in the miscellaneous cutout family are presented as sketches in Figure 28.

In summary, the family groups contained relatively isolated defects in all the ship types. Some doorways had cracks in the surrounding plating at radiused and collared corners when located in high stressed areas. Air holes were relatively problem free except in inaccessible places. Drain holes were susceptible to several problems; however, more are needed in machinery spaces and ballast tanks. Causes for the few lap failures were questionable. Lightening holes should be eliminated except where useful for safety and economic purposes. Pipeway failures were due mostly to locations and workmanship. Wireways were nearly free from defects. Weld clearance cracks were most prevalent with many reasons cited for their problem.

FAMILY NUMBER 8 - CLEARANCE CUTOUTS

Ninety-eight percent of the clearance cutouts shown in Figure 29 were functionally sound. Each cutout detail was placed in one of five groups according to its geometrical shape or attachment to the interrupting structural member. Results from this grouping are summarized in Table 11 and show that groups "B", "C" and "E" have the highest percent of sound details, whereas groups "A" and "D" have the highest percent of failures. Samples of failed detail modes are given in Figure 30.

Group "A" details were generally limited to cutouts in brackets supporting bulwarks with failures occurring as cracks at the welded corners of the cutouts. The reduction in shear area is the apparent cause of these failures.

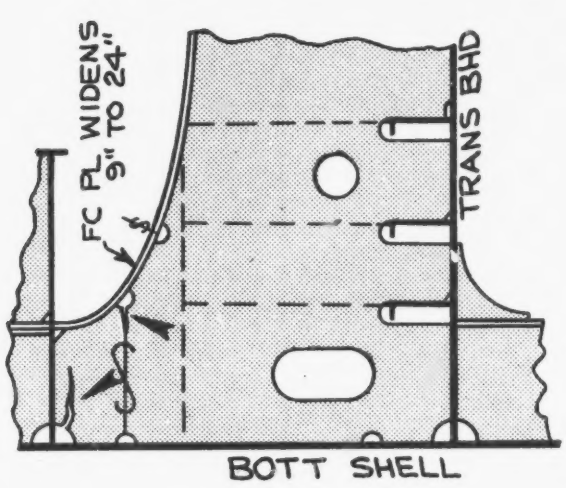
The failures in the group "B" details included those located too close to other cutouts, corrosion, and weld undercuts. Figure 31 is a photograph showing a cutout located too close to a deck access opening.

Heavy weather and rough fabrication cuts were the probable causes for the cracks developing in the configurations of details 8-C 2, 8-C-3, 8-C-5.

Group "D" experienced the highest number of observed failures. It also included the largest number of observed repairs. Failure cracks were prone to be at the angle heel corner of the cutout and were considered to be primarily due to high notch factors. Figures 32 and 33 are illustrations of the failure mode. Both figures show a short crack that has started at an angle heel. Rewelding the crack does not appear to be the best repair technique as verified by the picture in Figure 34 which is of a clearance cutout in a web frame. The cutout permits passage of a side shell longitudinal. Two almost parallel weld beads originated from a corner of the cutout and reveals a history of cracks. Beads of welds where cracks had possibly occurred were relatively common on a few ships. At times, something extra, such as a pad or a flat bar stiffener similar to the one on the web frame, had been added in an effort to prevent future cracks.

FIGURE 28

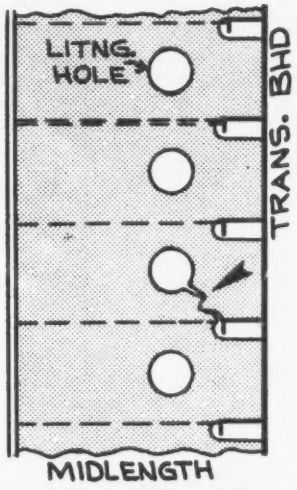
SAMPLE MISCELLANEOUS CUTOUT FAILURES



O.T. BHD WEB

DET MC 100

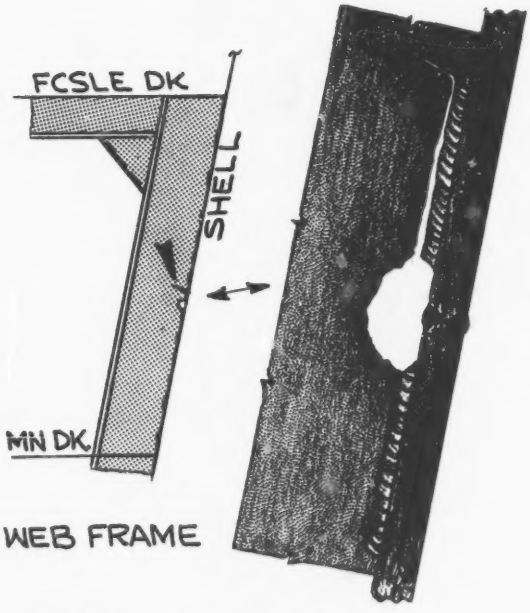
TANKER



O.T. BHD WEB

DET MC 101

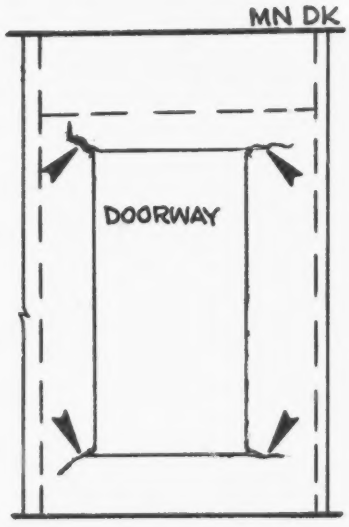
TANKER



WEB FRAME

DET CC 11

CONTAINERSHIP



MISC NT BHD

DET MC 102

NAVY

(Cont'd next page)

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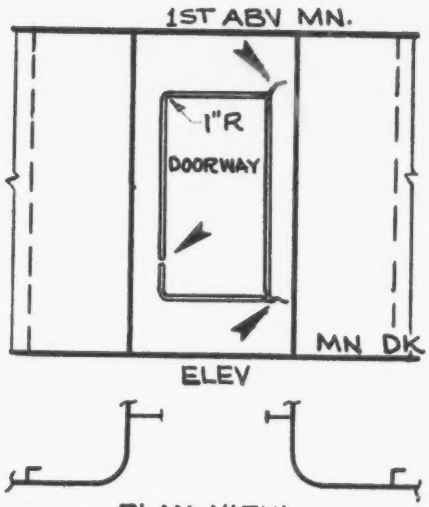
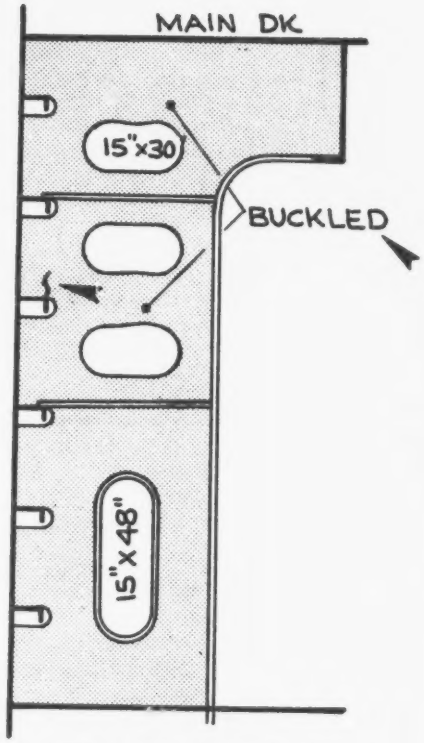
FIGURE 28, Sample Miscellaneous Cutout Failures (Cont'd)



LONGL ENCL. BHD & P&S

DET MC 103

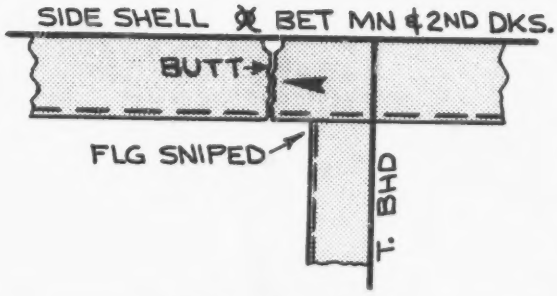
GENRL CARGO



TRANS WEB FR

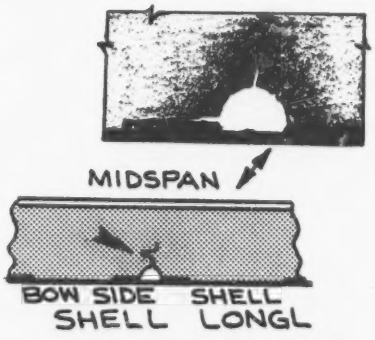
DET MC 104

COMBINATION CARRIER



DET MC 105

COMBINATION CARRIER



DET MC 106

COMBINATION CARRIER

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FIGURE 29

CLEARANCE CUTOUTS DETAILS
FAMILY NO. 8

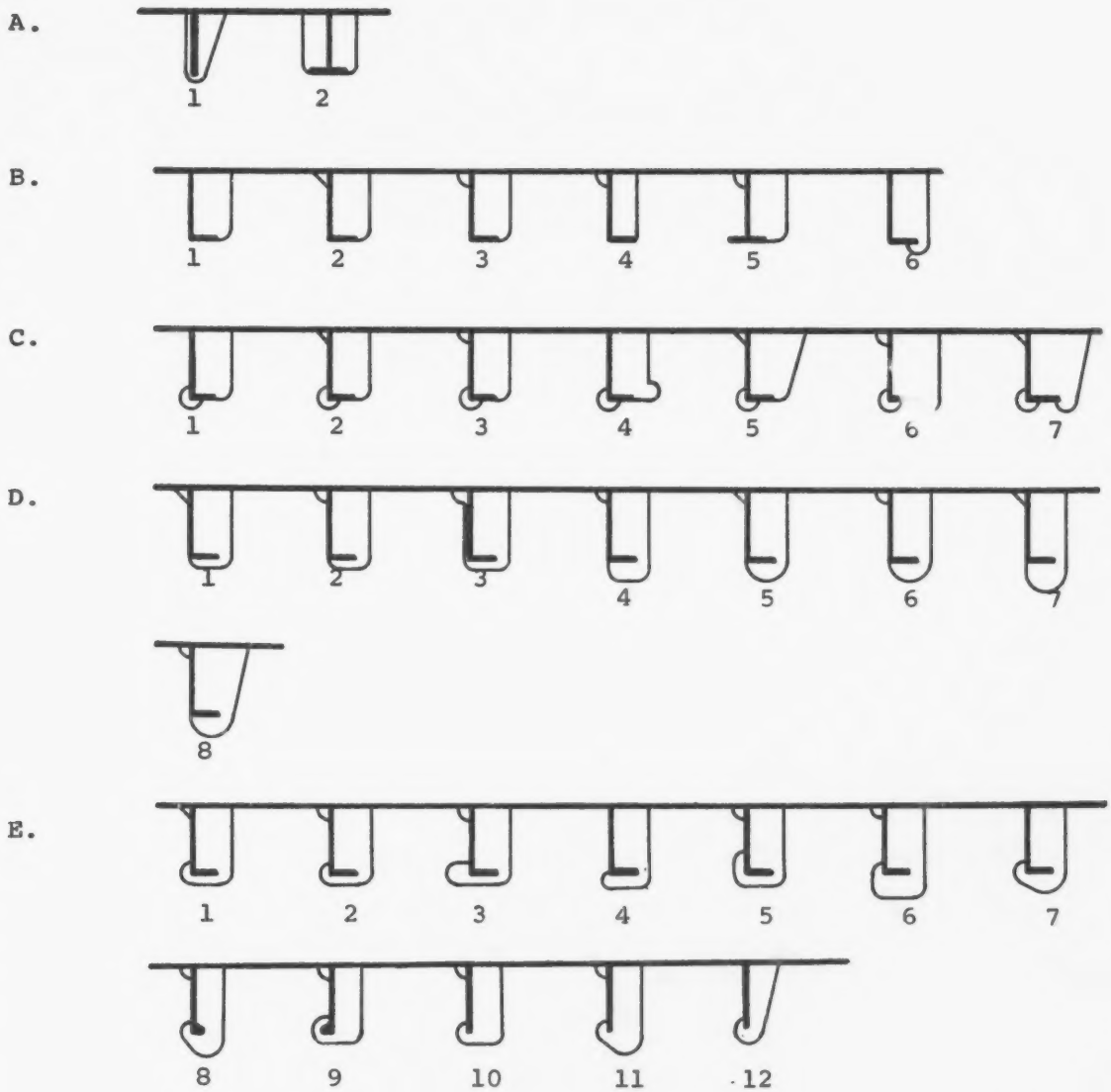

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TABLE 11

SUMMARY OF CLEARANCE CUTOUTS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	420	384	91.4	700	40	5.7
B	6220	6190	99.5	14450	37	.3
C	9040	8965	99.2	36200	97	.3
D	14080	13487	95.8	47200	792	1.7
E	18750	18663	99.5	64050	110	.2
TOTAL	48510	47689	98.3	162600	1076	.7

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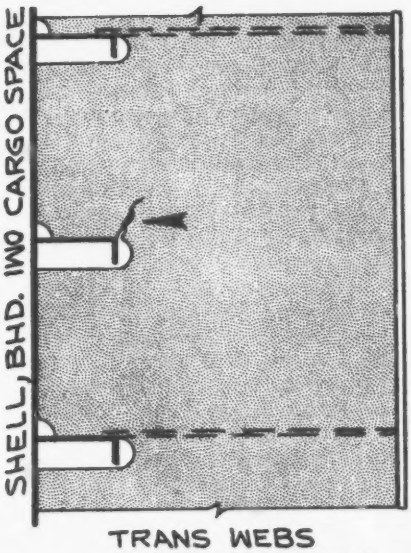
FIGURE 30

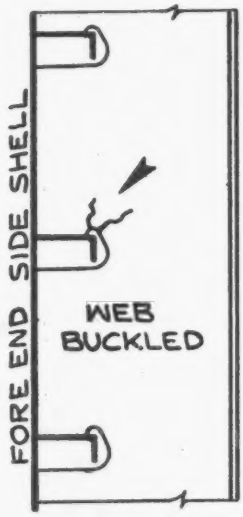
SAMPLE CLEARANCE CUT FAILURES



TRANS WEBS

DET CC 100

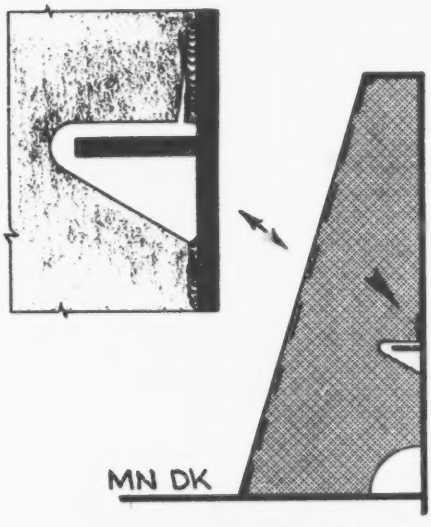
COMBINATION CARRIER, TANKER



TRANS WEBS

DET CC 101

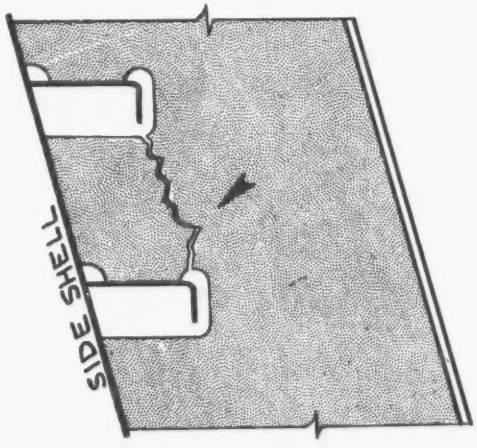
COMBINATION CARRIER



BULWARK AT MIDSHIP DKHSE

DET CC 102

GENRL CARGO



WEB FRAME IN FWD DEEP TANK

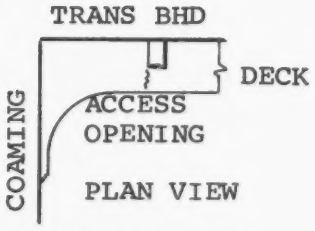
DET CC 103

BULK CARRIER

BEST DOCUMENT AVAILABLE

FIGURE 31

FAILED CLEARANCE CUT AT AN ACCESS OPENING ON A COMBINATION CARRIER



KEY TO PHOTO

The view is looking down at the side of an access opening in a platform deck aft but forward of the machinery space. The crack is between the clearance cutout, detail 8-B-2, and the larger access opening.

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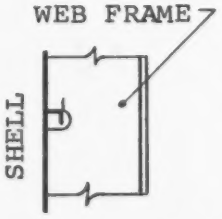
FIGURE 32

FAILURE MODE FOR GROUP "D" CLEARANCE
CUTOUTS ON A COMBINATION CARRIER

The view is of a detail 8-D-6 cutout around a shell longitudinal piercing a transverse web frame. The cracks at these cutouts are invariably in the plating at the through stiffener heel.

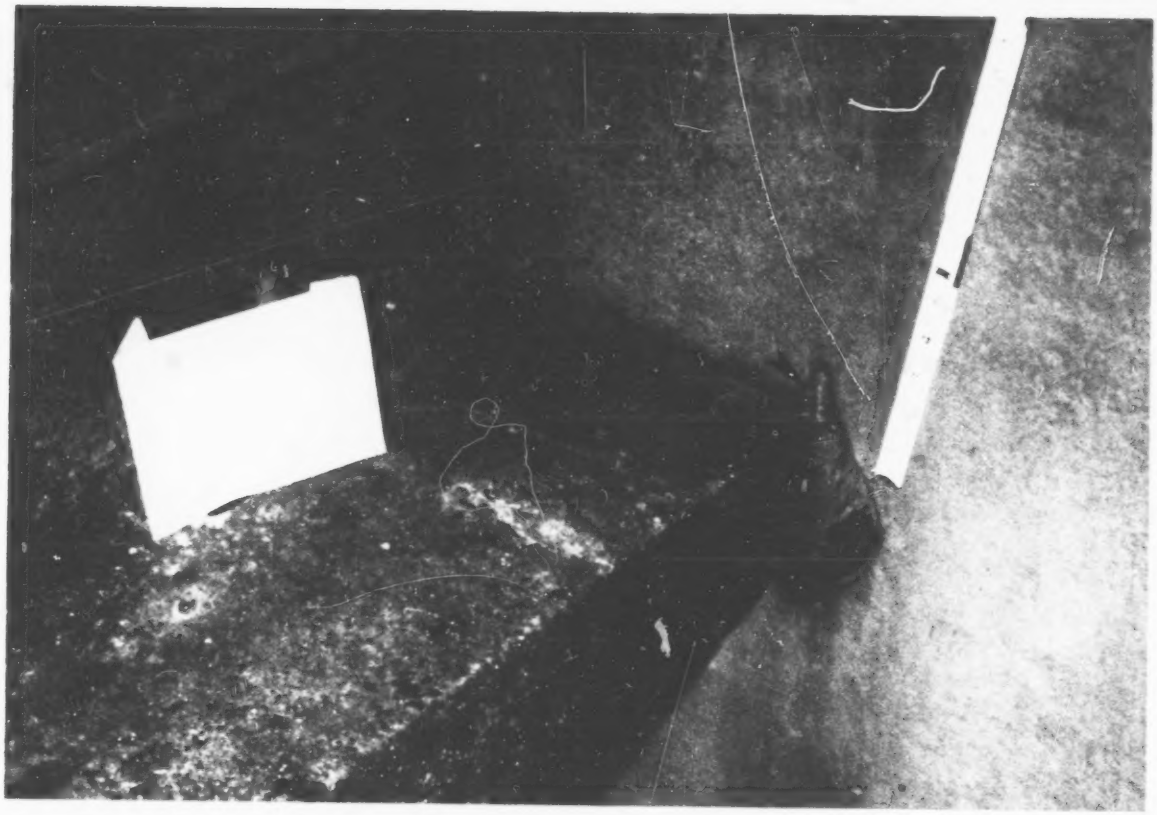


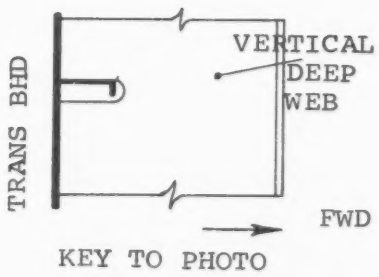
KEY TO PHOTO

BEST DOCUMENT AVAILABLE

FIGURE 33

FAILURE MODE FOR GROUP "D" CLEARANCE
CUTOUTS ON A TANKER





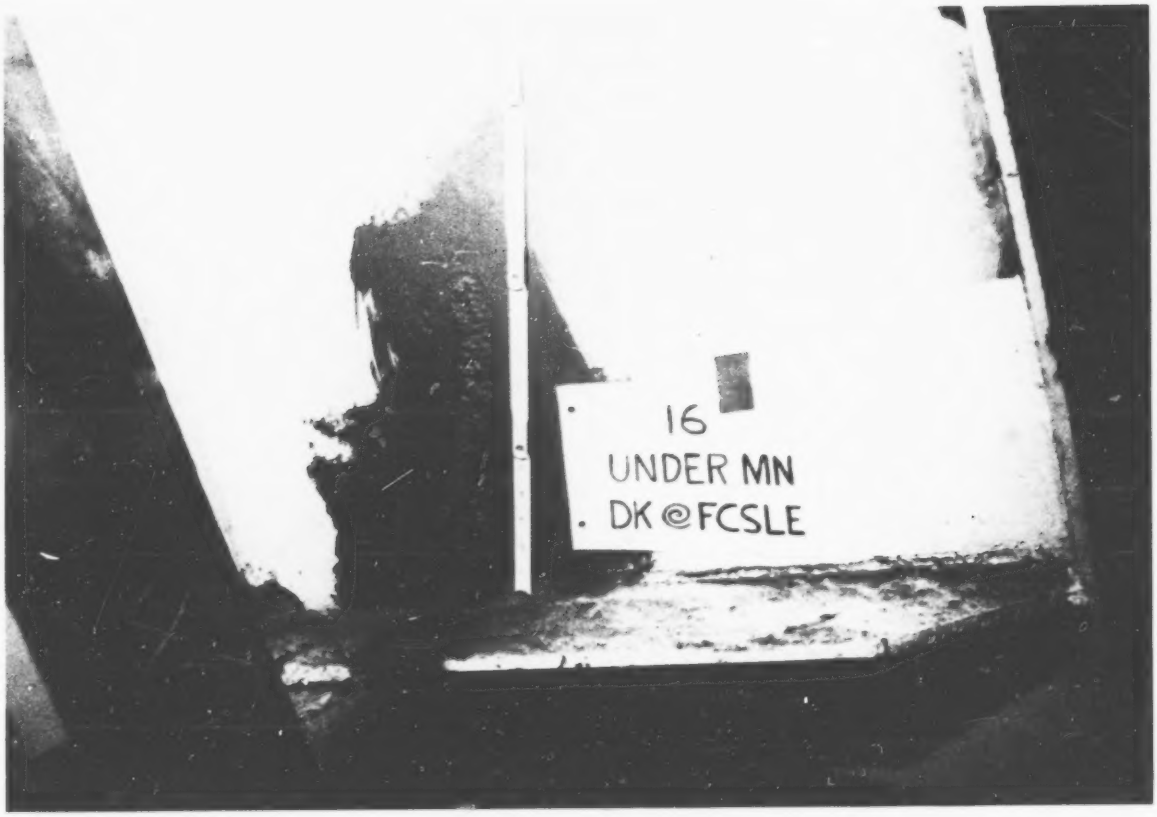
KEY TO PHOTO

The view is of a detail 8-D-6 cutout around a horizontal stiffener piercing a vertical web on the transverse oil tight bulkhead. The expected failure mode is a crack in the plating at the stiffener heel.

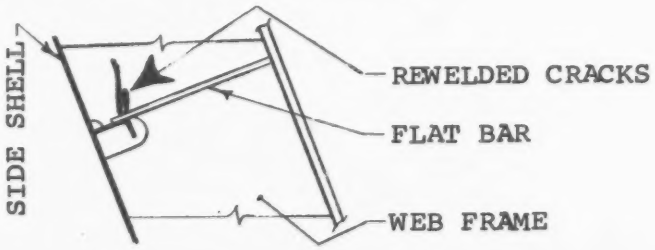
BEST DOCUMENT AVAILABLE

FIGURE 34

REPAIRED CLEARANCE CUT FAILURE
ON A COMBINATION CARRIER



Photograph shows rewelded cracks in web of side shell web frame in forward cargo hold - combination carrier, (see key plan below). Item with 45 chalk number is a wooden batten over shell longitudinals.



KEY PLAN FOR PHOTO

BEST DOCUMENT AVAILABLE

Group "E" had the largest percentage of non-failures (99.8%). The remaining small percentage (.2%) of the group that experienced failures were limited to details 8-E-2, 8-E-5, 8-E-6, and 8-E-7 and were found on bulk carriers, combination carriers, containerships, general cargo ships and tankers. Cracks occurred at the cutout corners particularly at the angle heel side as shown in Figure 35. In one unusual case a crack was in between the two corners as depicted in Figure 36. Another photograph of a failed group "E" cutout is in Figure 37.

A suggested improvement in group "E" designs is given in Reference 6, which suggests that a desirable ratio of corner radius to opening width is from one-fourth to one-eighth for minor openings in ship steel structures.

A recent study (Reference 7) of cracks around clearance cutouts indicated that vibration of bottom transverses was one failure cause, in addition to effects from fatigue and stress distribution patterns around the cutouts. Shipboard physical environment and loading patterns are also significant as indicated from the results of this survey.

In summary, each cutout group had failures, however, sound details made up over 98% of the total cutouts. Failures were in the cut plate at the welded corner in those details that had no web connections to the through structural shape. Most failures, however, were in the form of cracks in the web plating at the through angle heel corner. Failures were present in all the ship types.

FAMILY NUMBER 9 - DECK CUTOUTS

The twenty-three deck cutouts are shown in three groups in Figure 38. There were only twelve failures in the 6030 observed details. Table 12 is a summary of the collected data.

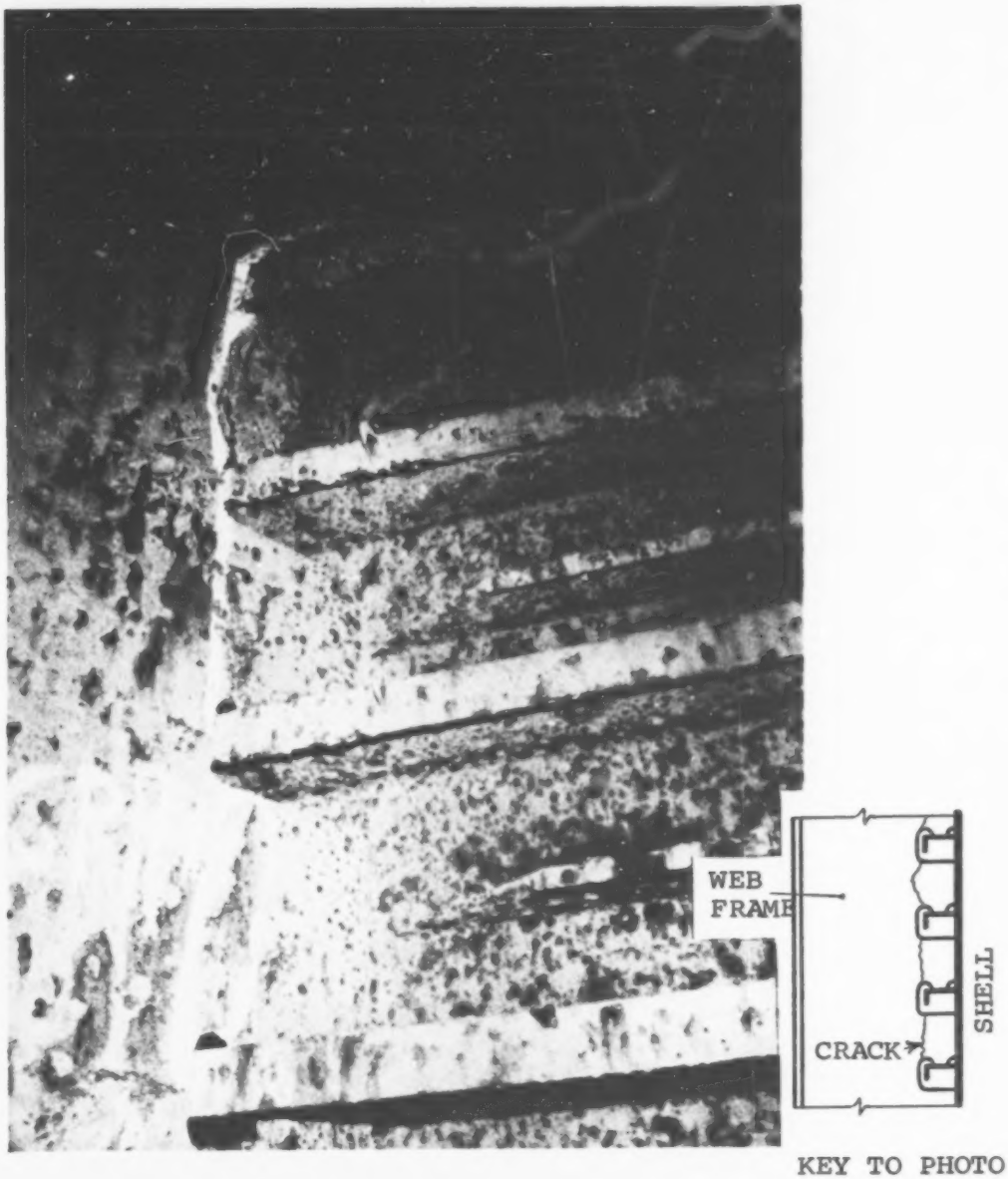
Groups "A" and "B" are relatively small deck openings that are normally used for access. Group "A" has openings with the surrounding deck plate edges unsupported except by a stiffening member a few inches from the hole. Group "B" has the plate edges supported by a flat bar either centered with, or on one side of, the deck plating. Sample deck cuts and failure modes are shown in the photographs of Figures 39 and 40.

Group "C" configurations are deck cuts at corners of large hatch openings. Existing failures in this group were limited to detail 9-C-2 which has a notch cut in the corner radius to allow the heel of vertical cell guides for containers to be recessed into the corner. This improperly designed corner contained cracks in the strength deck which originated from the indention and had progressed about ten inches as shown in the photograph of Figure 40.

A critical historical failure originated at the radius corner of a forward hatch opening in a containership. A crack appeared in the main deck plating at the forwardmost starboard hatch corner and grew

FIGURE 35

FAILED GROUP "E" CLEARANCE
CUTOUTS ON A BULK CARRIER



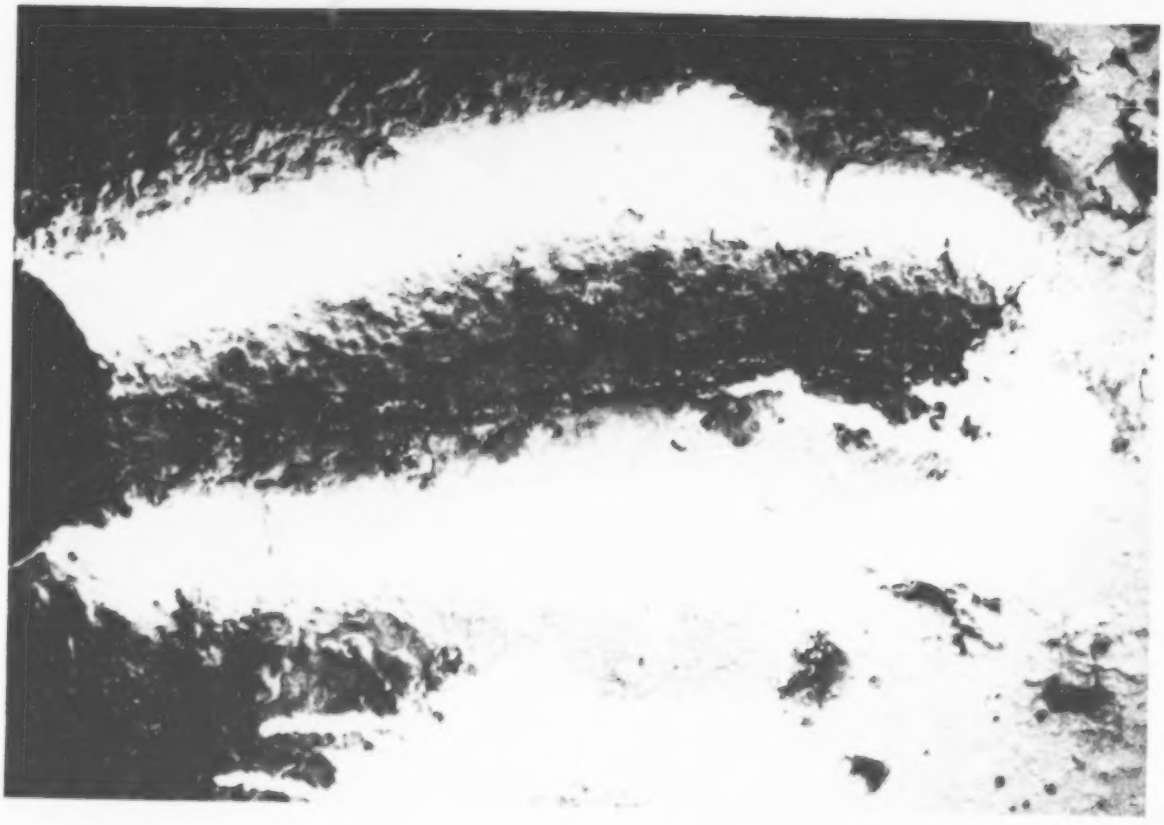
KEY TO PHOTO

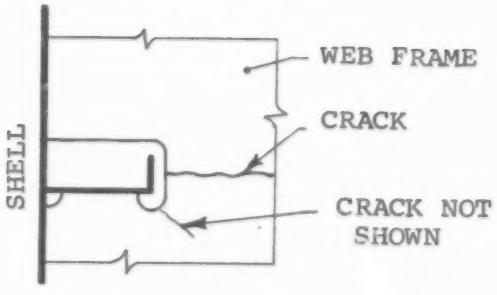
The view is of detail 8-E-2 cutouts in a side shell web frame which allows passage of the through shell longitudinals in the forward deep tank. Cracks that continue from cutout to cutout parallel the paint marks.

BEST DOCUMENT AVAILABLE

FIGURE 36

UNUSUAL CRACK AT A GROUP "E"
CLEARANCE CUTOUT ON A BULK CARRIER





KEY TO PHOTO

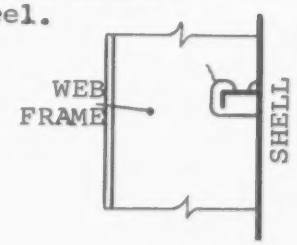
The fourteen inch crack is in a side shell web at a detail 8-E-2 cutout in the same forward deep tank as in Figure 34. Note the deterioration due to corrosion.

BEST DOCUMENT AVAILABLE

FIGURE 37

FAILED GROUP "E" CLEARANCE
CUTOUT ON A TANKER

The cutout is in a shell web frame between upper and forecastle decks. Flaked paint indicates the crack in the web plating at the through angle heel.

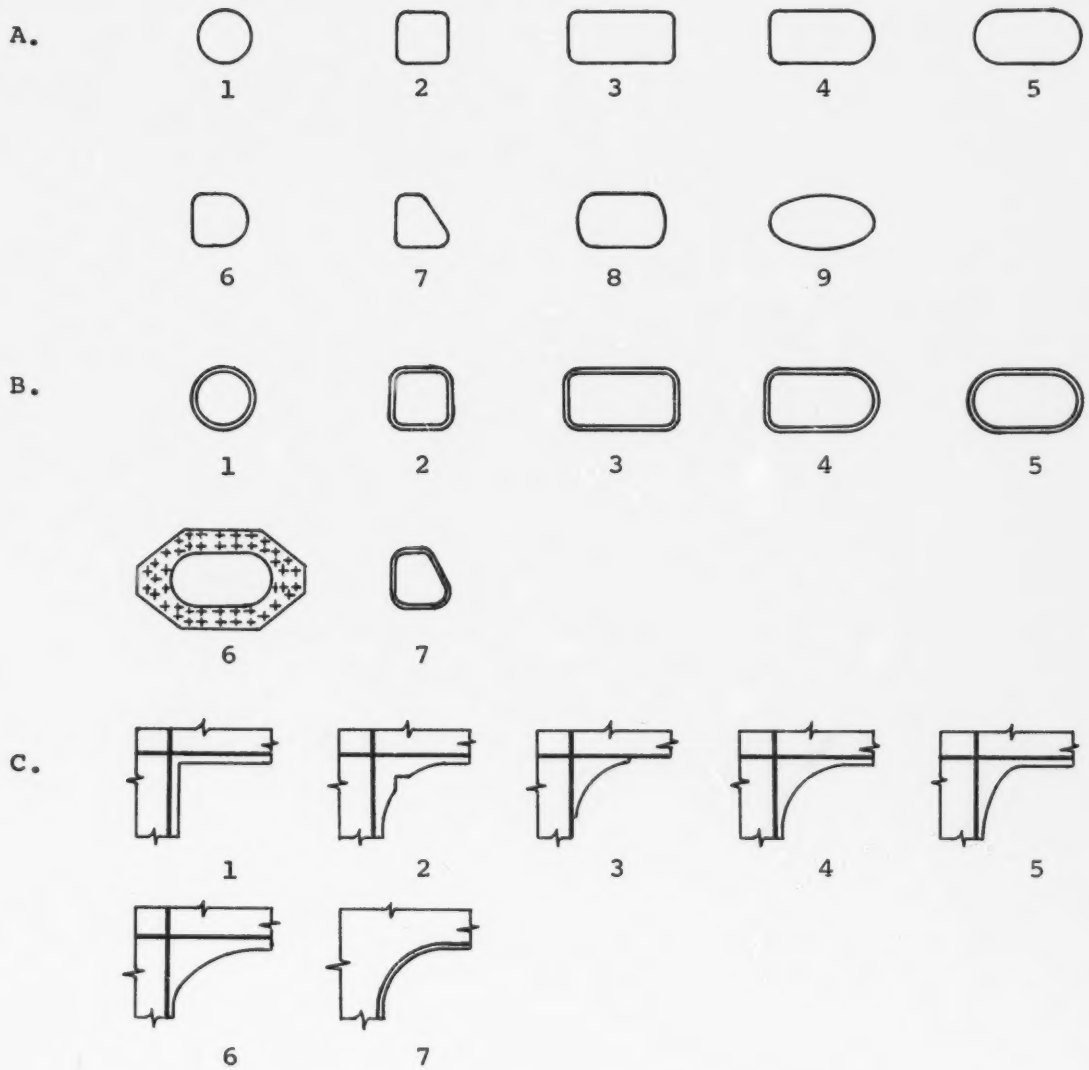


KEY TO PHOTO

BEST DOCUMENT AVAILABLE

FIGURE 38

DECK CUTOUT DETAILS
FAMILY NO. 9



BEST DOCUMENT AVAILABLE

TABLE 12

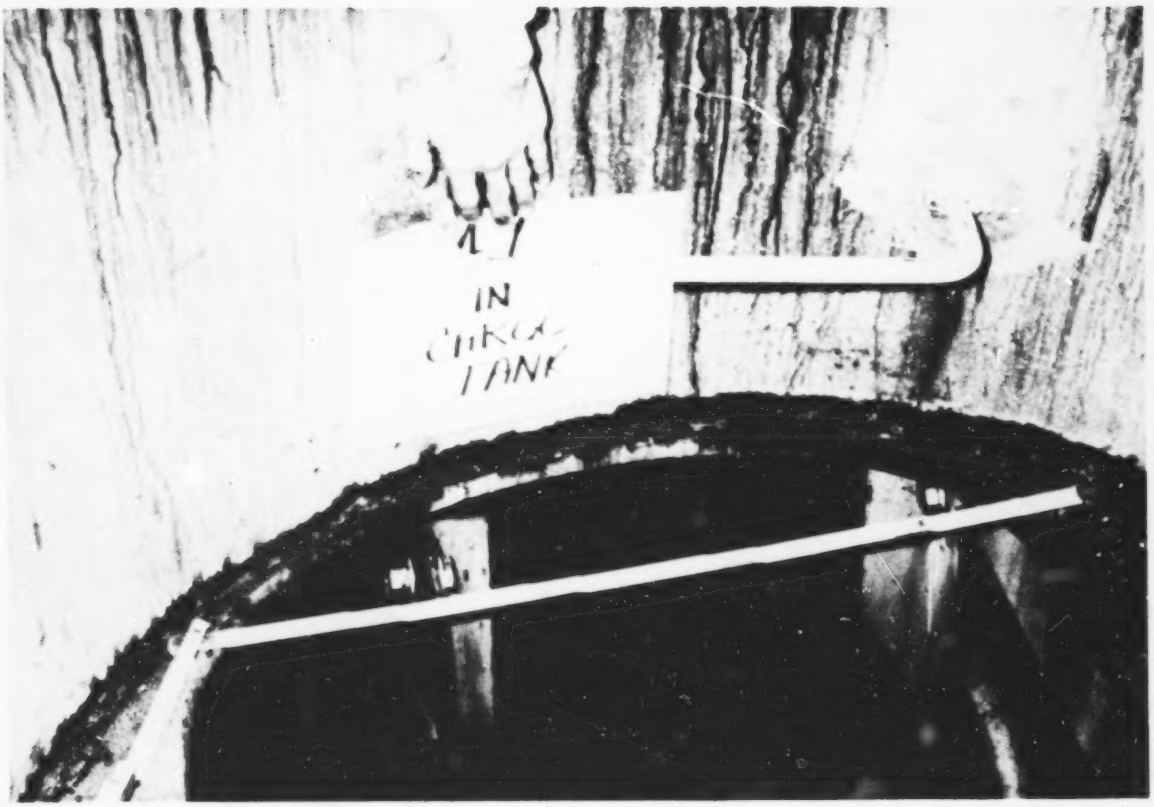
SUMMARY OF STRUCTURAL DECK CUTS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	2630	2629	100.0	3840	1	.0
B	2490	2485	99.8	3900	7	.2
C	910	904	99.3	1920	6	.3
TOTAL	6030	6018	99.8	9660	14	.1

BEST DOCUMENT AVAILABLE

FIGURE 39

SAMPLE DECK CUTOUT ON A TANKER



The picture is on the forward end of a main cargo tank access opening in upper deck. This particular tank was relativcly free from corrosion but note the renewed bolts holding the clips to the ladder. This opening, similar to detail 9-A-8, has no failure.

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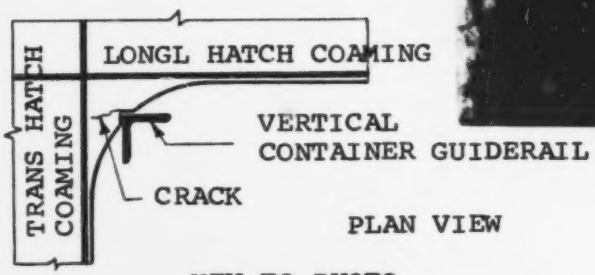
FIGURE 40

FAILED HATCH CORNER ON A COMBINATION CARRIER



PLAN VIEW

KEY TO PHOTO

This view is looking down at a radius hatch corner similar to detail 9-C-2. A notch has been cut in the deck plating to accommodate the vertical container cell guide. A ten inch crack in the plating originated at the notch.

BEST DOCUMENT AVAILABLE

several feet in length to within three feet of the shell. The repair included replacing the hatch corner deck plate with a higher strength material and adding a reinforcing longitudinal girder. Outboard of the new plate the crack was rewelded as shown at the outboard end of the folding ruler in Figure 41. The folding ruler is laying on the new plate in the approximate location where the crack existed between the hatch corner and the rewelded portion of the crack.

In summary, emphasis should be placed on the configuration of all openings in the strength deck. Even with the small number of failures observed, it should be remembered that only one crack propagating in a strength deck can lead to a catastrophe.

FAMILY NUMBER 10 - STANCHION ENDS

The seventy-nine observed stanchion ends were placed in three groups; (A) includes the connections at the top of the circular stanchions, (B) includes all of the stanchion bottom connections, and (C) includes all of the connections at the top of "H" stanchions. These groups are shown in Figure 42 with a summary of the numerical results presented in Table 13.

The summary of numerical results show the highest observed failure rate (2.2%) in the group "A" details. In general, cracks developed in or at the connections to the attachment structure, although in a few cases local identations were observed in stanchions near their ends. All of the stanchions were straight and in plane except for one ship where exposed stanchions were distorted from horizontal impact loads.

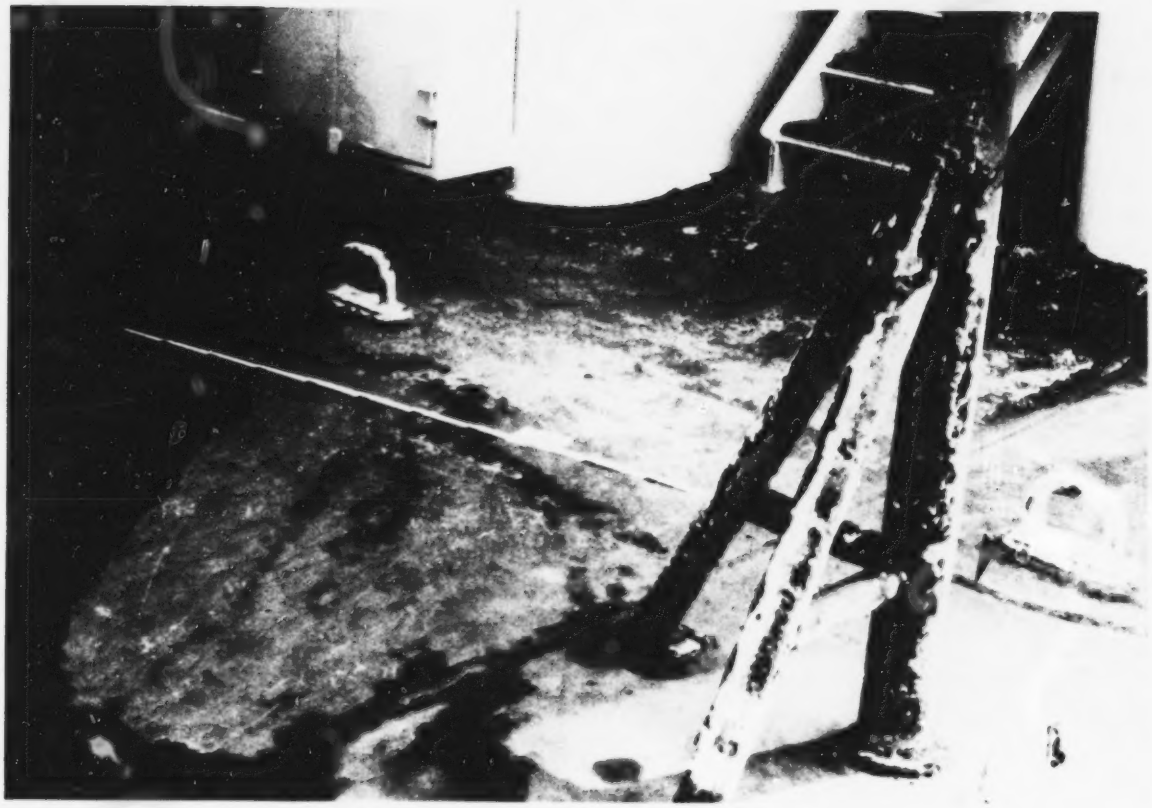
Defects were observed in details 10-A-1, 10-A-2, 10-A-12, 10-B-9, 10-B-21, 10-B-22, 10-B-24, 10-B-25, 10-C-1, and 10-C-5 inclusive. Connections to the main deck-house on containerships and tankers accounted for most of these details. Detail 10-B-9 is the bracket connection between two container stands and in every case where they were oriented fore and aft on the main deck of a ship, the welded connection between the brackets was cracked.

Sample failure modes, depicted in Figures 43, 44, and 45, show tension failure due to an unusual design combined with a heavy side shell load, and cracks and buckles due to relative motions between main deck-houses and the side shell. Figure 44 contains a photograph of the crack problem noted above for detail 10-B-9. Figure 45 is a distorted stanchion on a general cargo ship.

In summary, the major portion of stanchion end failures occurred in deck-house connections, in container stand brackets, and at the ends of exposed pillars on a cargo ship. The design for the container stand brackets should be modified to delete the notch effect at their intersections. Cracks associated with deck-house stanchion connection should be analyzed in relation to interractive motions between the deck-house and ship.

FIGURE 41

HISTORICAL CRACK AT A HATCH
CORNER ON A CONTAINERSHIP



This view is on the starboard side of the ship and looking down on the main deck plating outboard of the forward corner of No. 1 main cargo hatch. The folding ruler is on the renewed deck plating and in the approximate location where the crack existed outboard of the hatch corner. Note the rewelded portion of the crack at the outboard end of the ruler.

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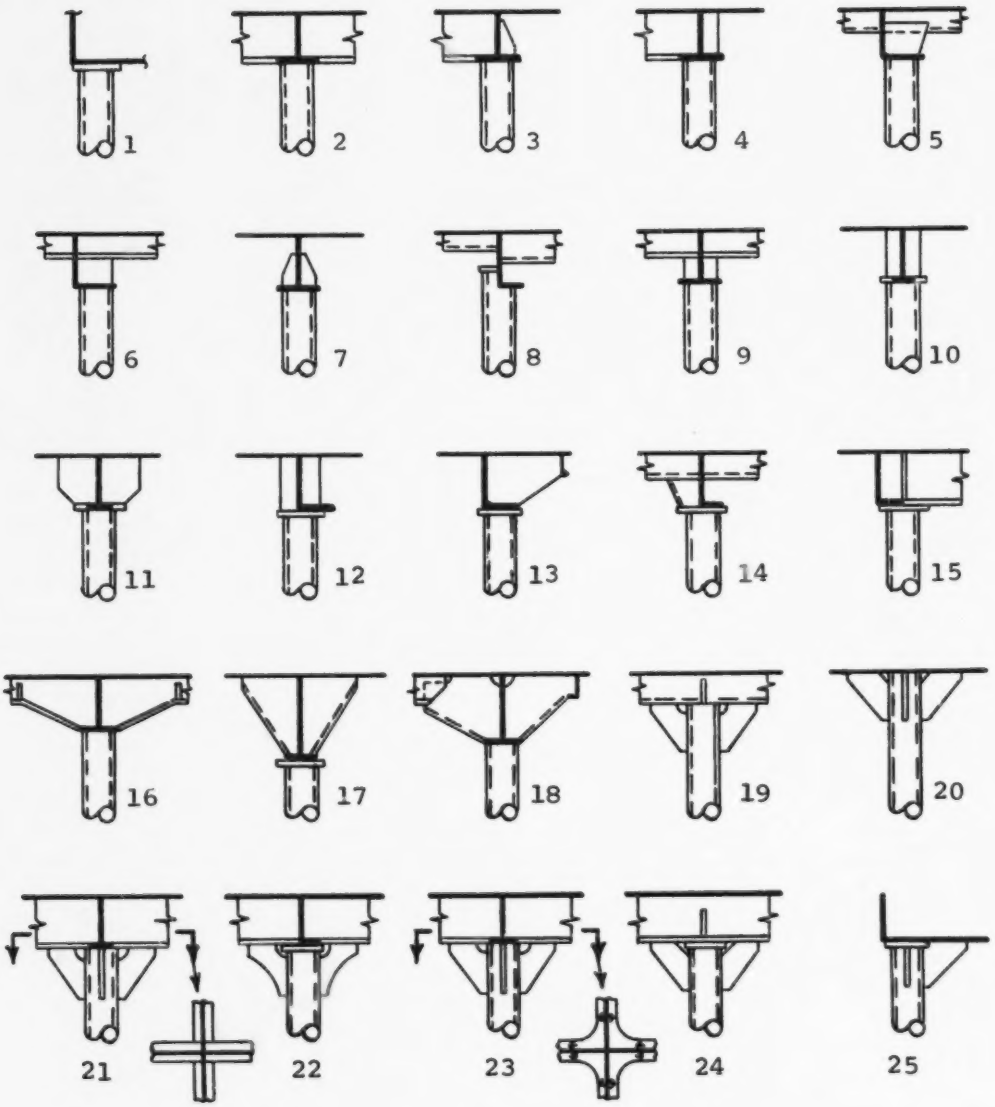
FIGURE 42

STANCHION END DETAILS
FAMILY NO. 10

A.



BEST DOCUMENT AVAILABLE

FIGURE 42 - STANCHION END DETAILS, Family No. 10 (Cont'd)

B.

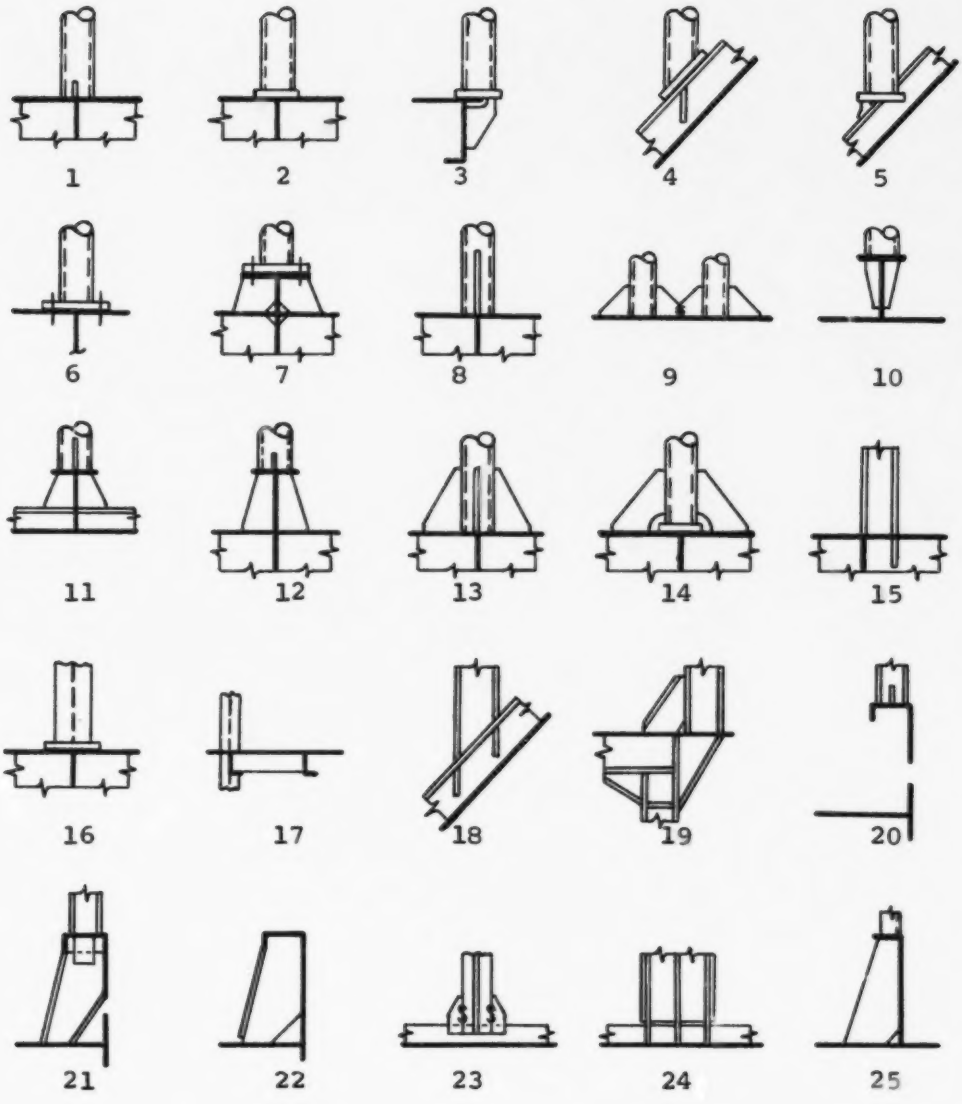


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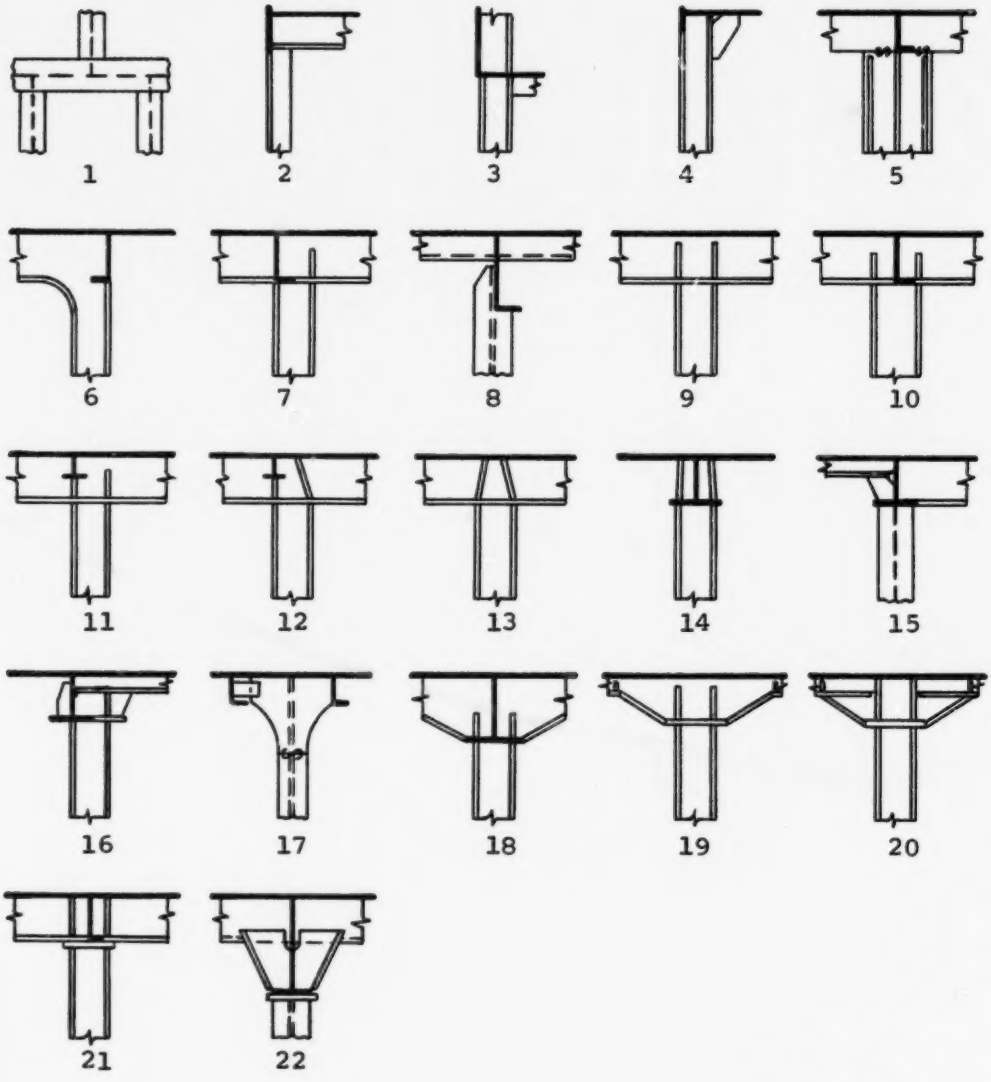
FIGURE 42 - STANCHION END DETAILS, Family No. 10 (Cont'd)

c.



BEST DOCUMENT AVAILABLE

FIGURE 42 - STANCHION END DETAILS, Family No. 10 (Cont'd)

C.
(Cont'd)

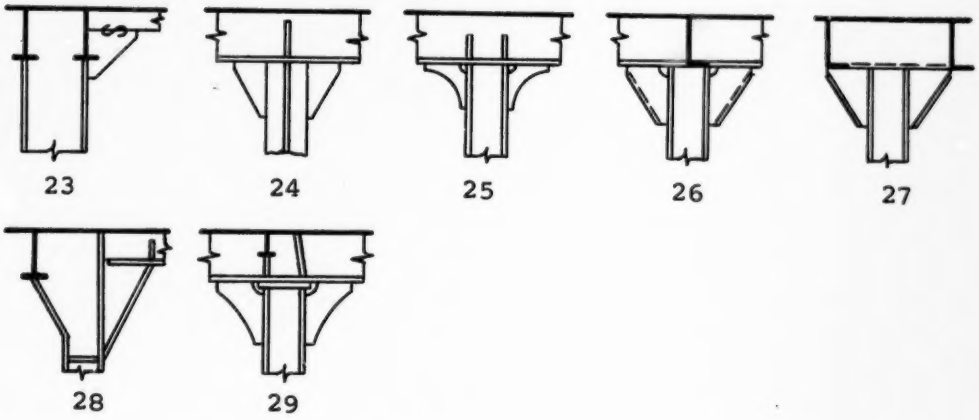


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TABLE 13

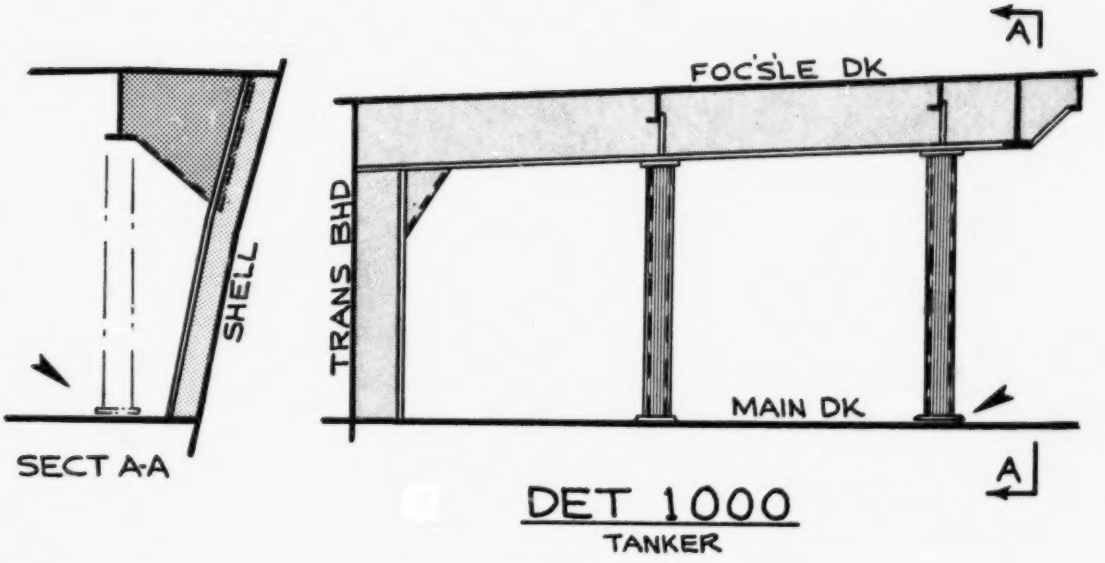
SUMMARY OF STANCHION ENDS

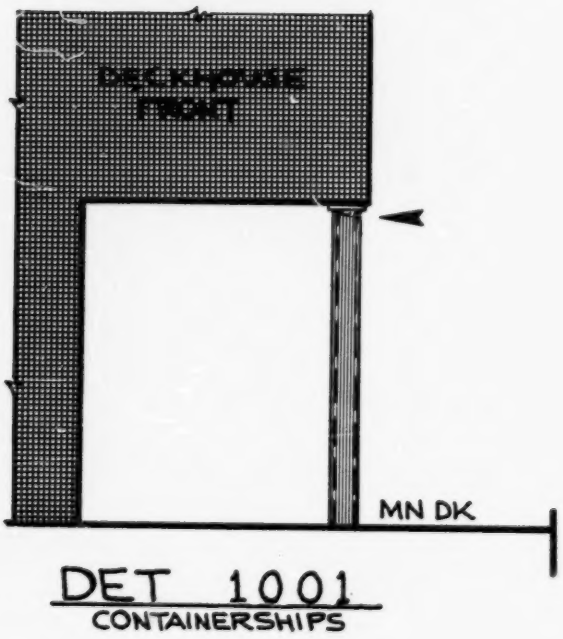
FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	2040	1995	97.8	2480	57	2.3
B	3140	3097	98.6	3970	45	1.1
C	1090	1080	99.3	1470	10	.5
TOTAL	6270	6172	98.4	7920	112	1.4

BEST DOCUMENT AVAILABLE

FIGURE 43

SAMPLE STANCHION END FAILURES





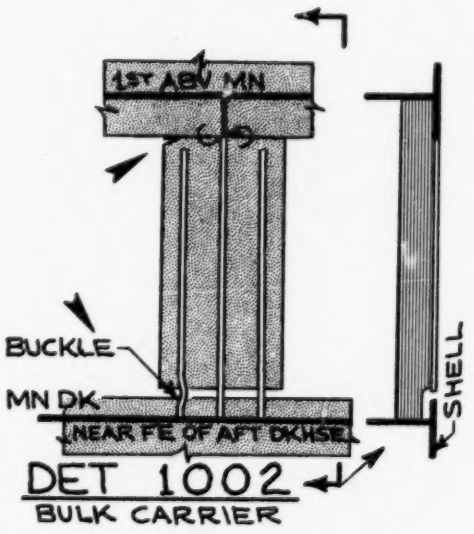


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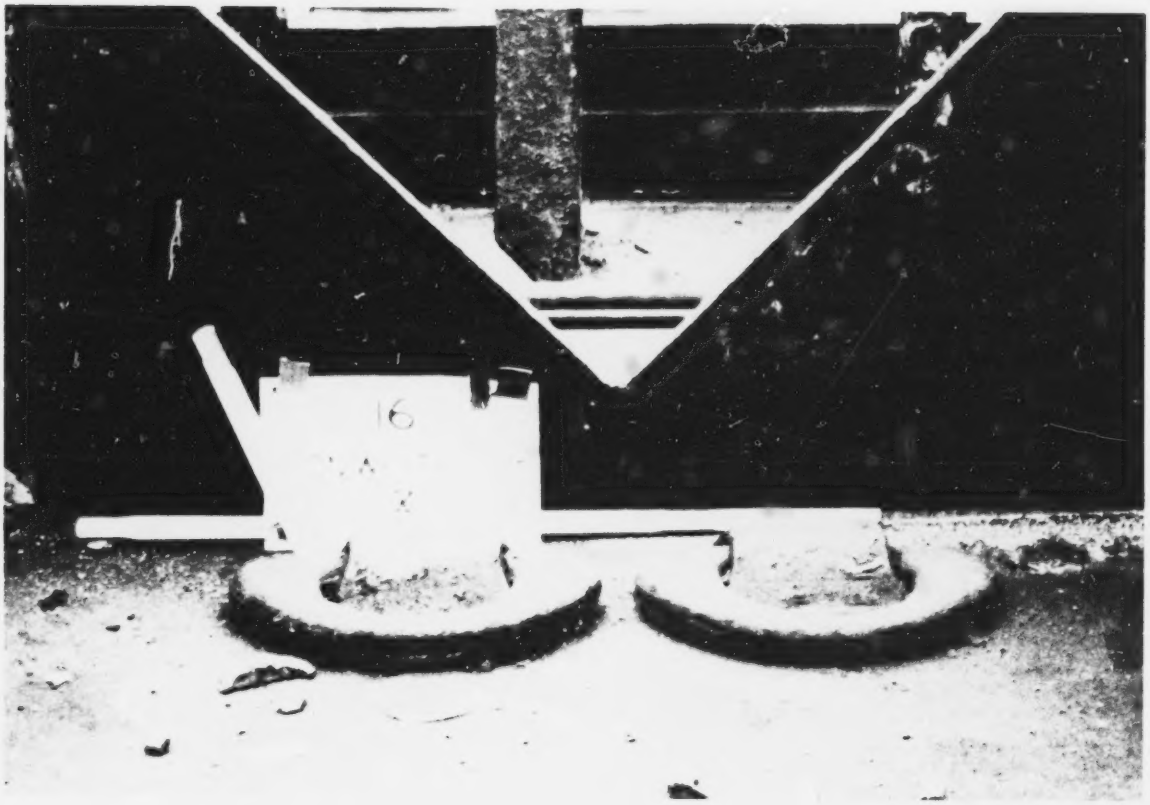
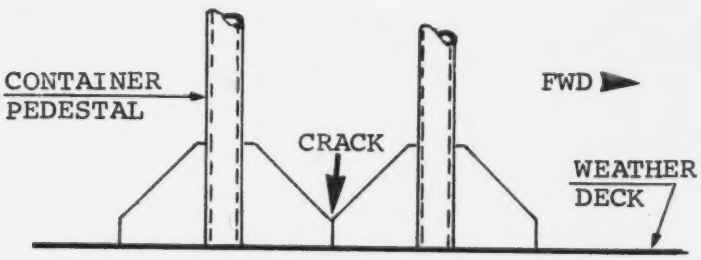
FIGURE 44

FAILED STANCHION END BRACKET
CONNECTION ON A COMBINATION CARRIER





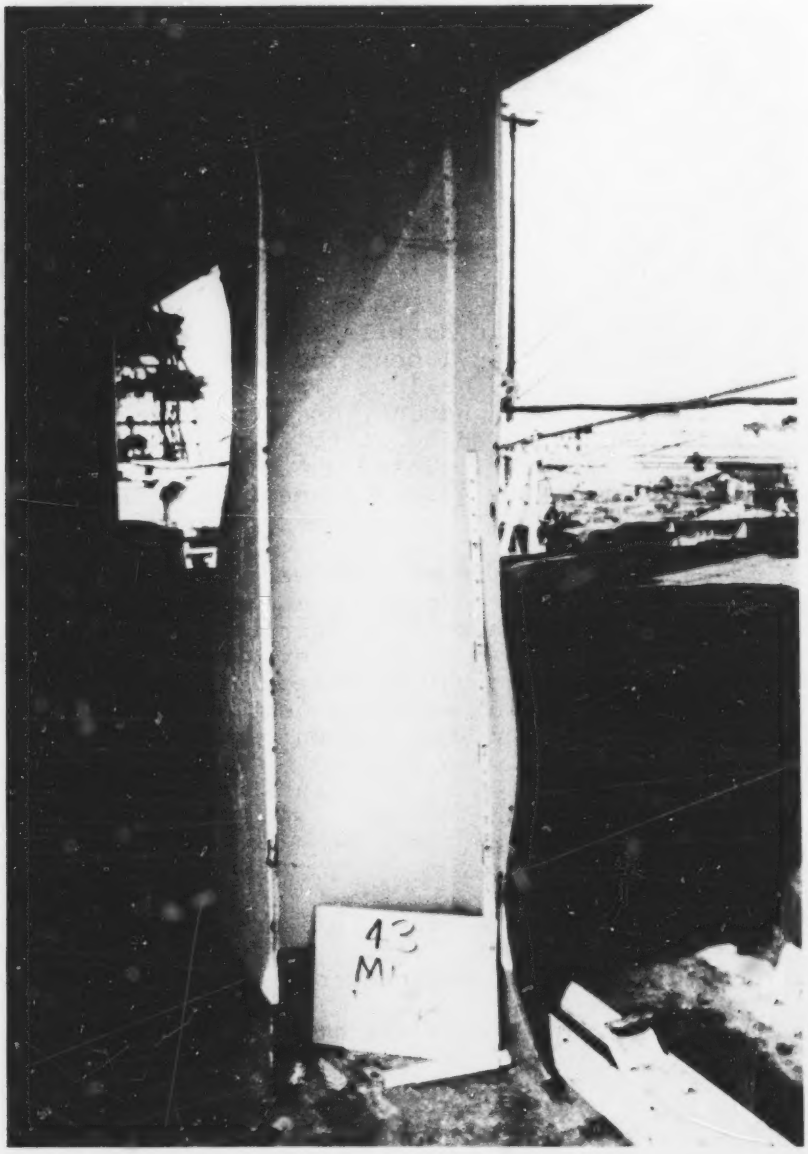
KEY TO PHOTO

View on weather deck looking outboard at the intersection of two container stand brackets, similar to detail 10-B-9. The crack originated at the vee notch and continued through the weld to the deck plating.

BEST DOCUMENT AVAILABLE

FIGURE 45

DISTORTED STANCHION ON A GENERAL CARGO SHIP



The stanchion supports equipment on a miscellaneous deck-house. Distortions in the flanges appear to be due to direct impact loading. Note the crack in the right hand flange near the top of the stanchion.

BEST DOCUMENT AVAILABLE

FAMILY NUMBER 11 - STIFFENER ENDS

In general, failures associated with stiffeners occur at the ends in the web of the stiffener or in the attached plate. For the purpose of classification, the stiffener ends included in this family are the ends of load carrying structural angles on tees that are attached to panels of plating. Thirty-three variations were observed and placed in one of the four groups shown in Figure 46. A summary of the numerical data is given in Table 14.

The overall success record of the 30,760 observed stiffener ends was 99.3%, however, the remaining 0.7% consisted of 229 failures with numerous causes which are attributed to shear, combination tension and shear, design, heavy seas, neglect, collisions, and tension in descending order.

The variations depicted in details 11-A-1, 11-A-2, 11-A-3, 11-A-5, 11-A-7, 11-A-9 and 11-B-1 contained over one-half of the total failures in the entire family. All of the seven variations were designed to perform the same function, however, when located on the forecastle enclosure bulkhead adjacent to main deck each variation sustained one or more failures. These details appear to have minor failures when located in other areas of the ship except at cargo, fuel or ballast tanks.

Failure modes at the stiffener ends were cracks in the stiffener web or in the stiffened bulkhead plating adjacent to the stiffener end, except for a few cases where stiffener webs were buckled or twisted. Sample failures shown on the sketches in Figure 47 include sniped stiffener webs on oil tight bulkheads. These sniped web stiffeners shown in detail 1101 were frequently associated with leaks in tank boundary bulkheads when used as the end configurations for stiffeners with relatively long spans. Other examples of cracks at stiffeners ends are depicted in Figures 48 and 49.

Failure distributions were 10% in the stern, 83% in the midship or cargo area and 7% in the bow.

Note the similarity to the distribution of 8%, 82%, and 10%, respectively for the total detail family failures. This is the closest correlation between the total percentages and an individual family.

In summary, several different variations were used for similar structural arrangements among the ships with snipe ended stiffeners frequently associated with cracks in tank boundary bulkheads.

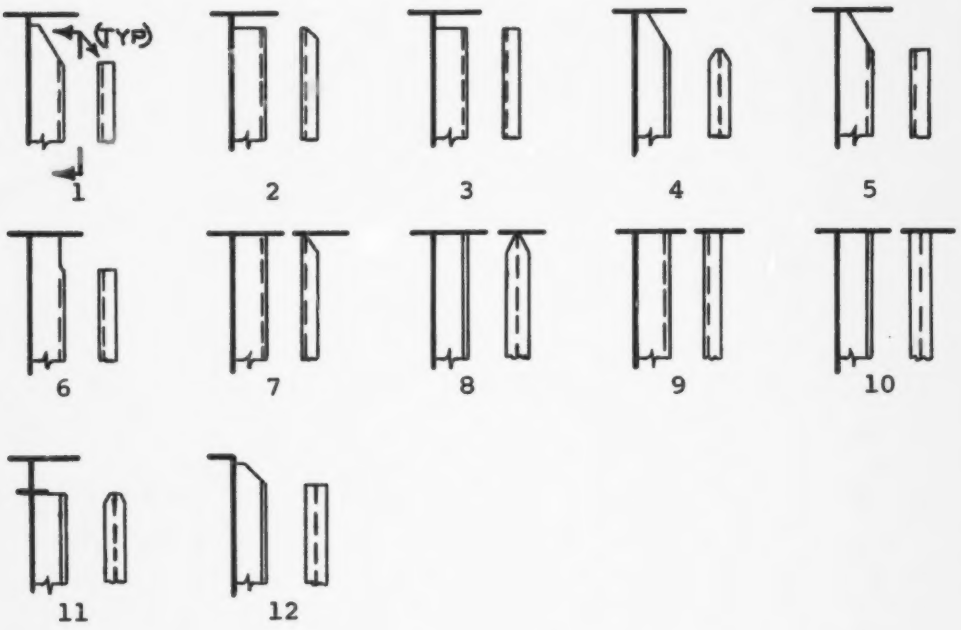
FAMILY NUMBER 12 - PANEL STIFFENERS

Panel stiffeners include those structural angles, tees, and flat bars welded to large panels of plating for the explicit purpose of preventing local instability of the plate. They are non-direct load carrying members. According to its shape and the function of the structural member it is attached to, each of the forty observed variations has been placed in one of the six groups shown in Figure 50. Numerical data is summarized in Table 15.

FIGURE 46

STIFFENER END DETAILS
FAMILY NO. 11

A.



B.

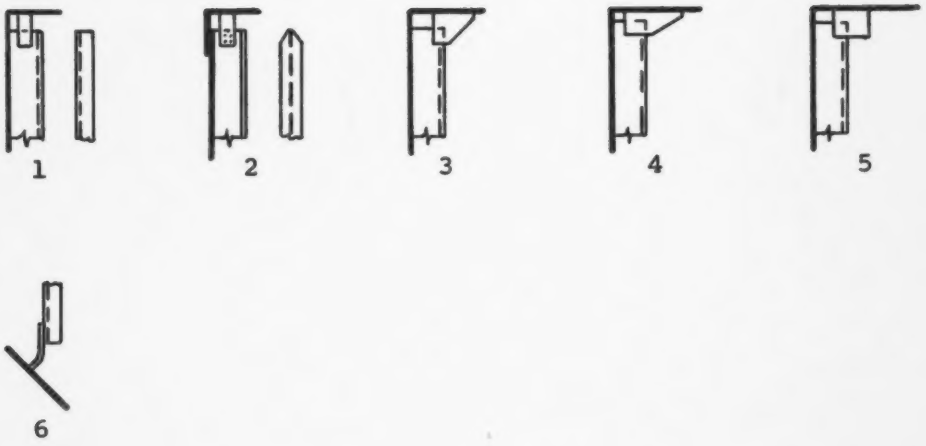


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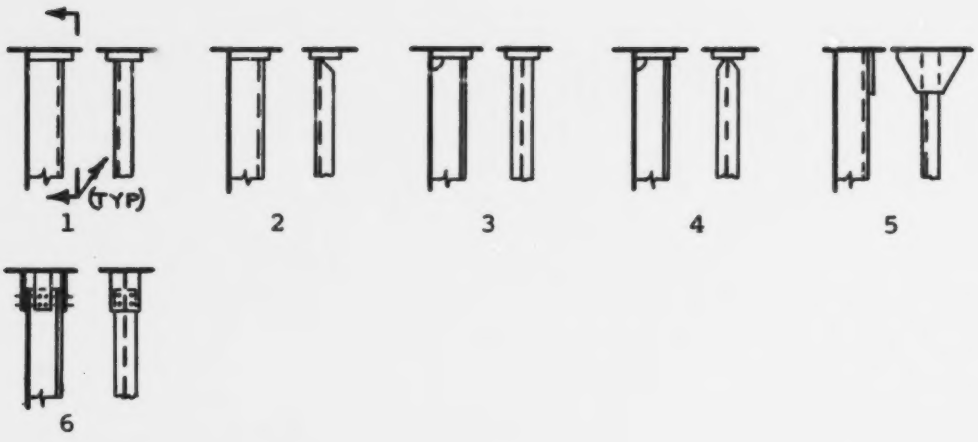
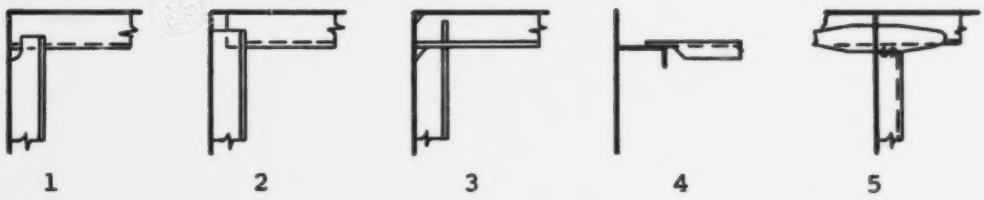
FIGURE 46 - STIFFENER END DETAILS, Family No. 11 (Cont'd)

C.



D.



E.

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TABLE 14

SUMMARY OF STIFFENER ENDS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	22080	21938	99.4	55950	180	.3
B	3370	3334	98.9	6940	44	.6
C	610	603	98.8	1230	8	.7
D	4470	4426	99.0	10330	56	.5
E	230	230	100.0	580	-	0
TOTAL	30760	30531	99.3	75030	288	.4

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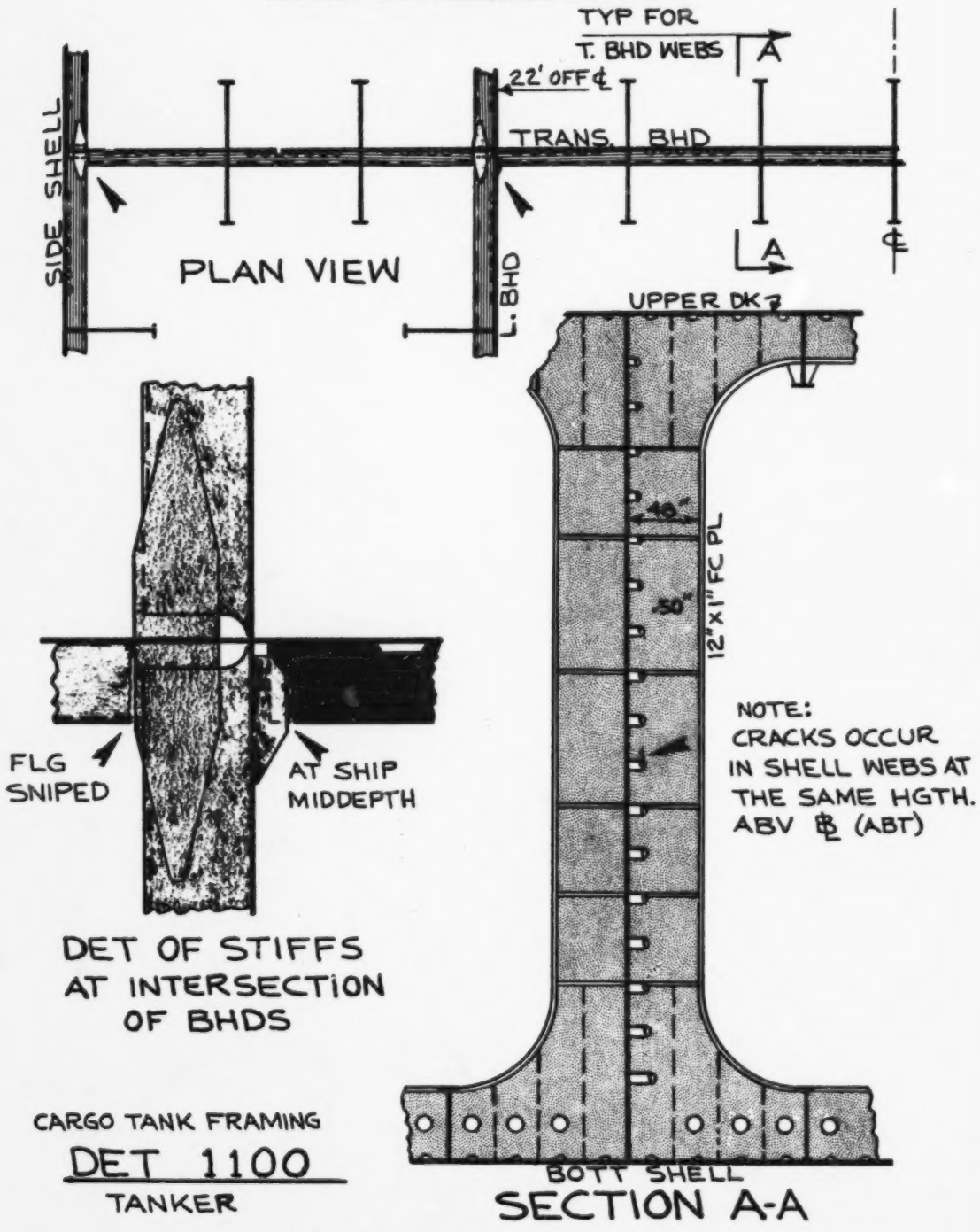
FIGURE 47

SAMPLE STIFFENER END FAILURES



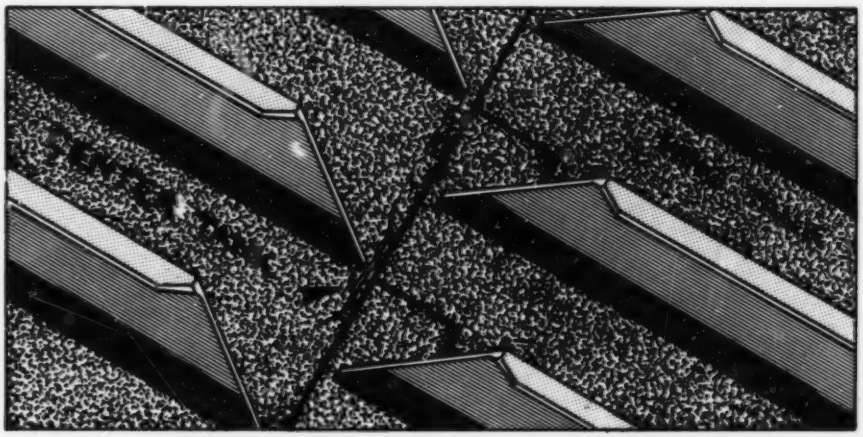
CARGO TANK FRAMING

DET 1100

TANKER

BEST DOCUMENT AVAILABLE

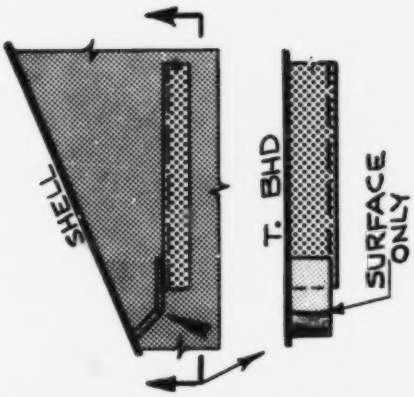
FIGURE 47 - SAMPLE STIFFENER END FAILURES (Cont'd)



TRANS. O.T. BHD.

DET 1101

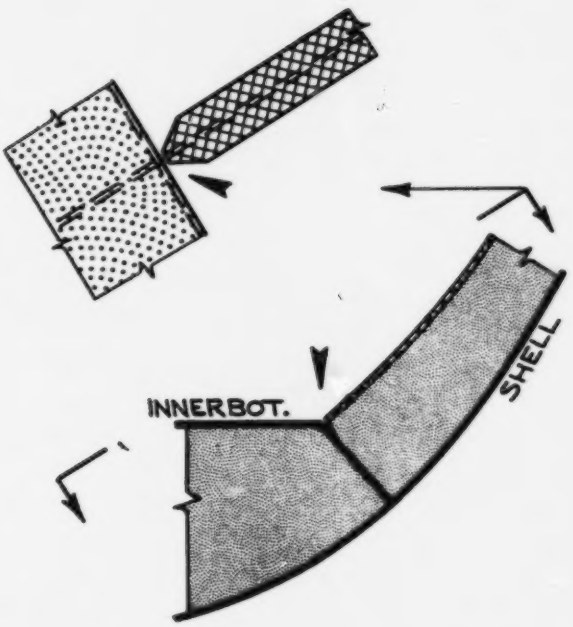
TANKER



BHD STIFFENING
FWD CARGO HOLD

DET 1102

CONTAINERSHIP



SHELL FRAMING

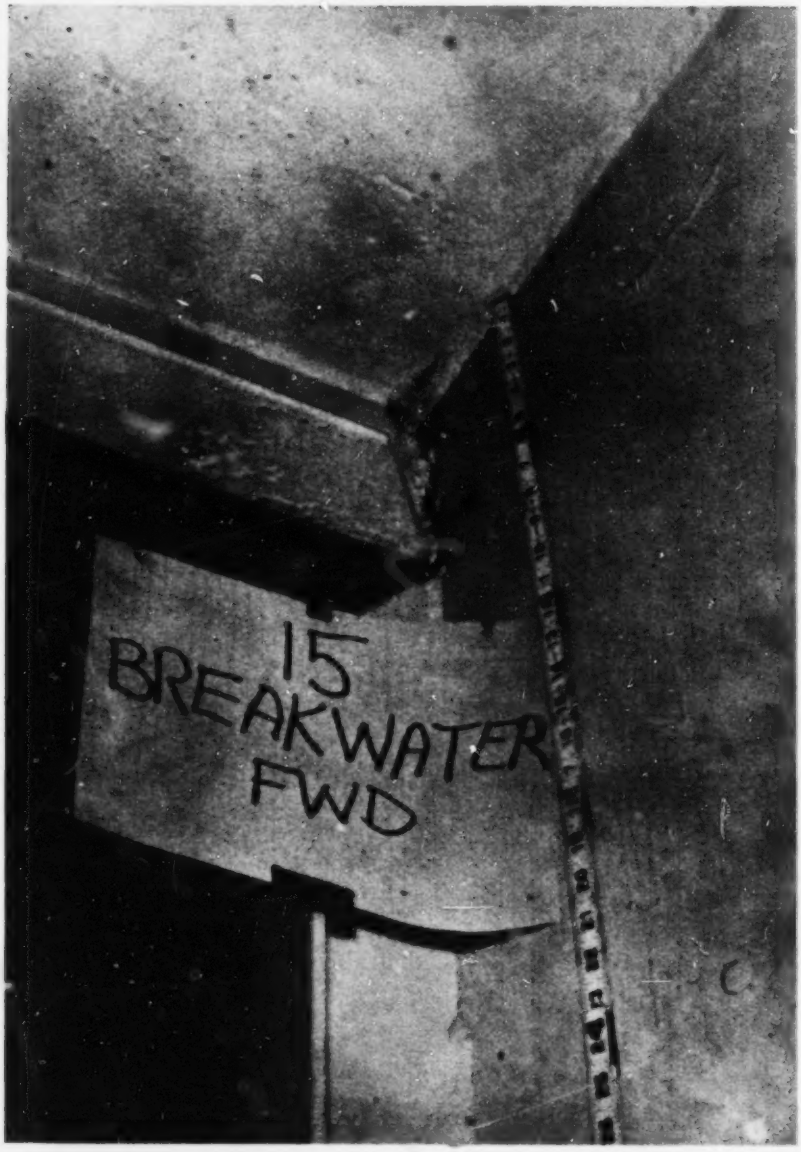
DET 1103

NAVY

BEST DOCUMENT AVAILABLE

FIGURE 48

FAILED STIFFENER END ON A COMBINATION CARRIER



The view is looking forward with the deck above as forecastle deck. The crack in the horizontal stiffener's web completely detached the stiffener from the longitudinal bulkhead plating. Note that the stiffener's flange is sniped as in detail 11-A-7.

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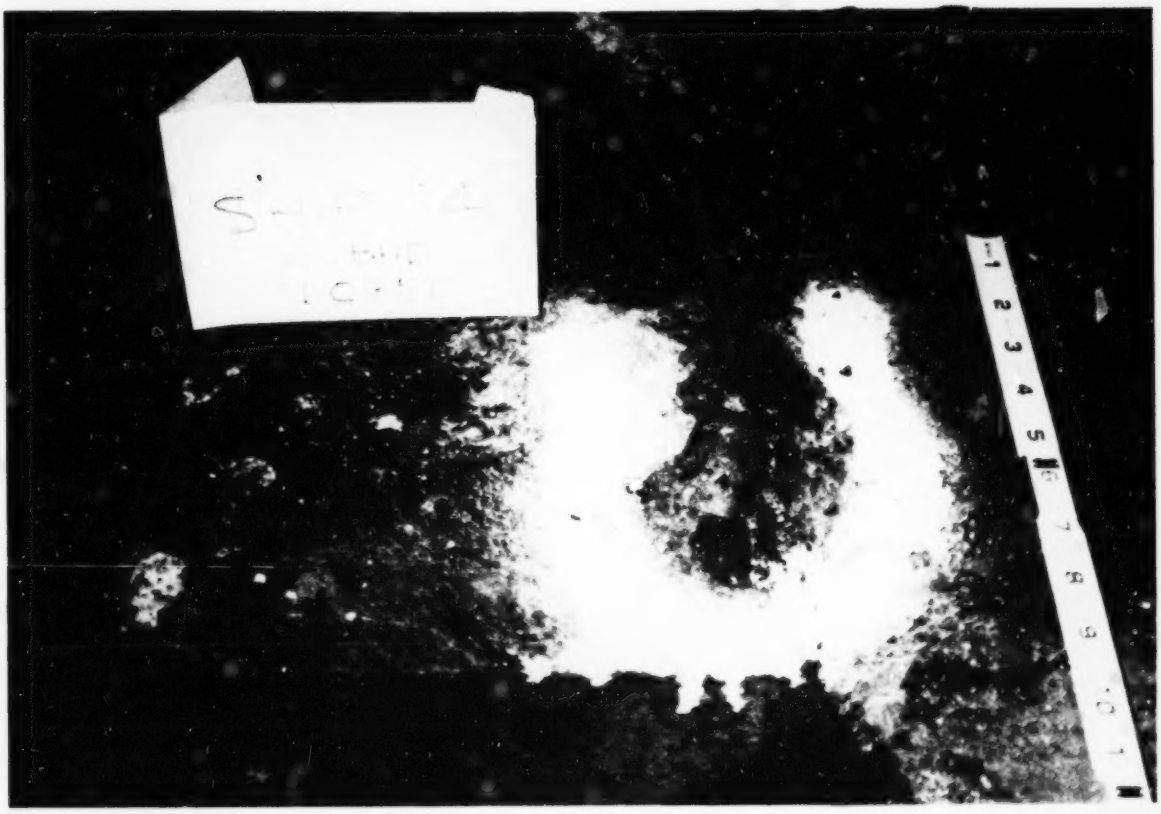
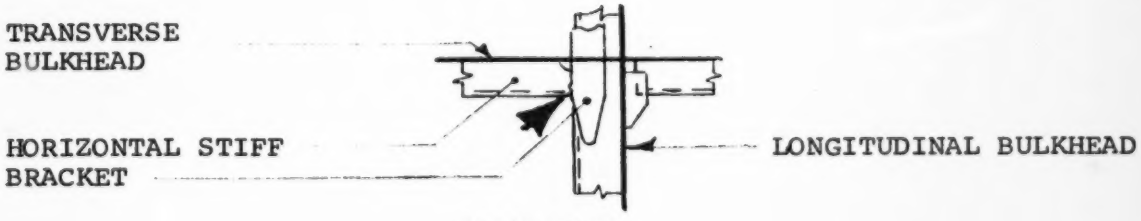
FIGURE 49

FAILED STIFFENER END ON A TANKER



Photograph shows a crack in a transverse bulkhead horizontal stiffener web at the connection to a bracket plate on the longitudinal bulkhead - tanker. See key plan below and Figure 47 detail 1100. Crack is encircled with white paint. The stiffener end is similar to detail 11-D-5.



PLAN VIEW

KEY PLAN FOR PHOTO

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FIGURE 50

PANEL STIFFENER DETAILS
FAMILY NO. 12

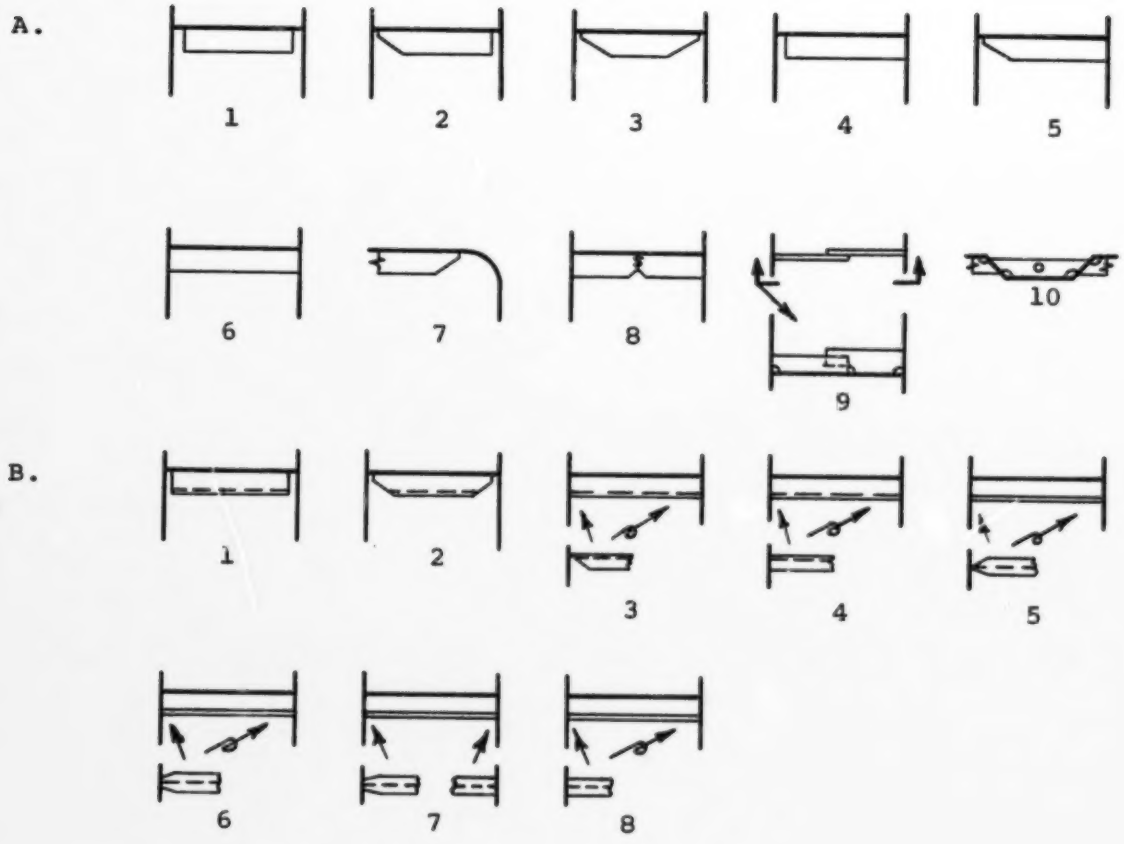
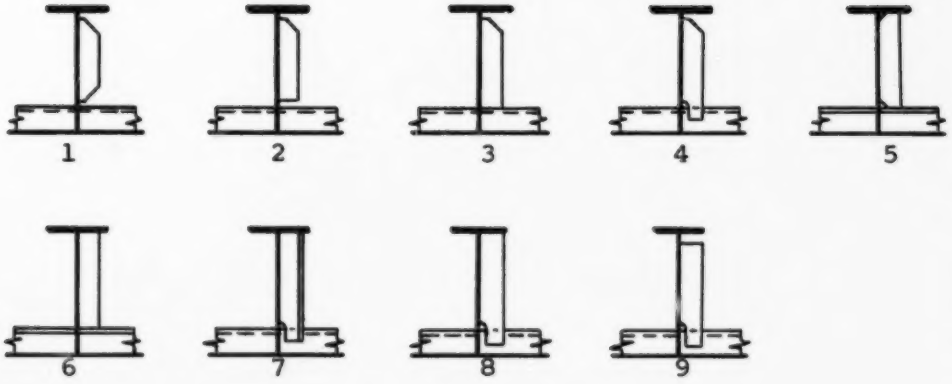


FIGURE 50 - PANEL STIFFENER DETAILS, Family No. 12 (Cont'd)

C.



D.

E.

F.

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TABLE 15

SUMMARY OF PANEL STIFFENERS

FAMILY GROUP	OBSERVED			ESTIMATED		
	Number of Details	No. of Sound Details	% Sound Details	Number of Details	No. of Failed Details	% Failed Details
A	13100	13015	99.4	32940	93	.3
B	9610	9592	99.8	25110	21	.1
C	15140	15100	99.7	37220	48	.1
D	1370	1270	92.7	3000	125	4.2
E	430	420	97.7	670	12	1.8
F	380	372	97.9	650	9	1.4
TOTAL	40030	39769	99.3	99590	308	.3

BEST DOCUMENT AVAILABLE

Of the 40,480 details observed in this family there were only 261 (0.6%) failures. Individually, however, group "D" had the most observed failed details (100) and the highest percentage of failures (7.3%). The large number of failures in this group is attributed to collisions or impact from large objects which resulted in loadings not anticipated in the design stage. Unnecessary fabrication notches also contributed to some of the failures. Failure modes associated with panel stiffeners are shown in Figure 51 which includes a crack in the attaching welds, in a stiffener end, and in plating at a stiffener end. Weld cracks in detail 1200 were due to inadequate welding and possibly elongation of the longitudinal corrugated bulkhead while the ship was in a seaway. In detail 1201, the crack resulted from the interaction of the shell longitudinal and panel stiffener at a cutout in the web frame in conjunction with the possible concurrent swashing loads from oil in the tank. Cracks in detail 1202 resulted from lateral distortion of the shell frame during a collision.

The photograph in Figure 52 shows a crack similar to detail 1201 in Figure 51. These cracks occurred on the bottom of cargo tanks as well as at mid depth. Figure 53 shows a buckled flat bar stiffener which has been subject to an unusual and local horizontal load on a miscellaneous bulkhead. Figure 54 contains a photograph of a reinforced panel stiffener on a transverse hatch coamway.

In summary, the most predominate cause of failures in panel stiffeners was collisions which distorted the stiffened plating. Detail 11-C-3 and possibly 11-C-4 through 11-C-9 should be strengthened at the connection to the longitudinal. Notches similar to the one in detail 11-A-8 should be avoided.

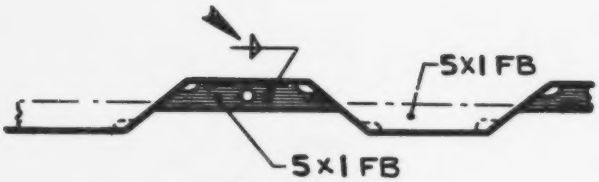
SUMMARY OF RESULTS

The data in this report were collected in a one year period. Twelve selected details used for structural connections were surveyed on fifty different ships in seven repair yards in the United States. Ships included in the survey were four Bulk Carriers, five Combination Carriers, twelve Containerships, five General Cargo, thirteen Tankers, nine Naval, and two Miscellaneous. The service age of the ships ranged from four to eight years and eleven to thirty years with the largest number of failures appearing in the ships with fourteen years service. The histogram of ship failures versus service age in Figure 55 shows that no conclusive age-failure pattern exists in this group of surveyed ships and indicates that correlation of age to failure is less significant than design, fabrication or maintenance.

The twelve details selected for survey were beam brackets, tripping brackets, non-tight collars, tight collars, gunwale connections, knife edge crossings, miscellaneous cutouts, clearance cuts, stanchion ends, stiffener ends, and panel stiffeners. These twelve details evolved into twelve families which included fifty-six groups of configuration variations. The twelve groups contained 553 distinct detail variations. Table 16 is a summary listing the total number of details and detail failures observed for each family. Additionally, the table includes the estimated total number of details and detail failures that could be anticipated on the fifty ships.

FIGURE 51

SAMPLE PANEL STIFFENER FAILURES

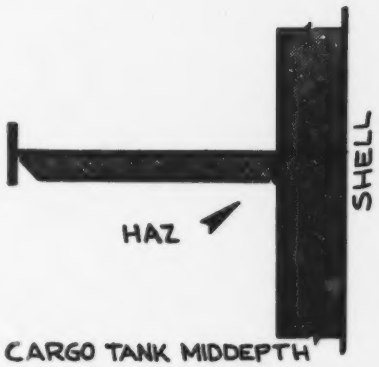


PLAN VIEW

FBS. 0 CORRUGATED L.BHD
CARGO HOLD AMIDSHIP

DET 1200

COMBINATION CARRIER

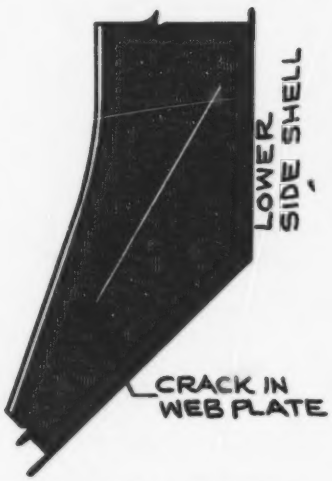


CARGO TANK MIDDEPTH

LONGL AT WEB FR

DET 1201

TANKER



CARGO HOLD OUTBD

SHELL FRAME

DET 1202

BULK CARRIER

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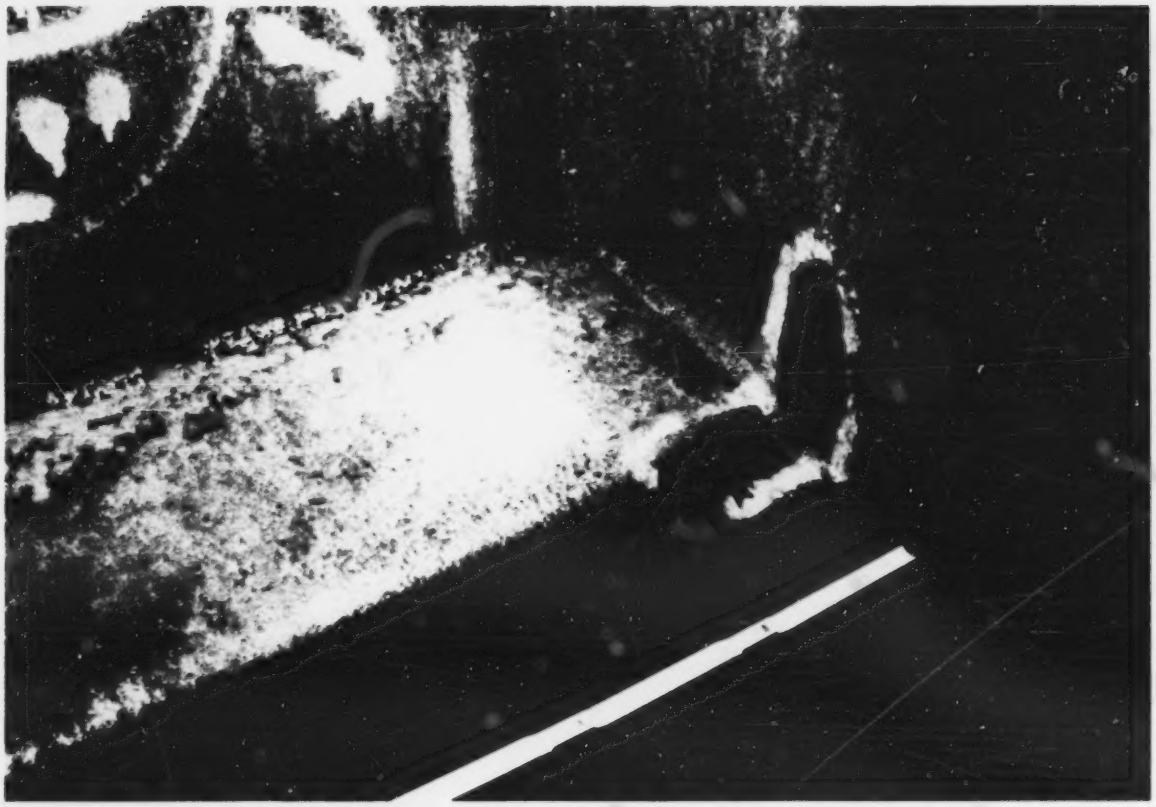
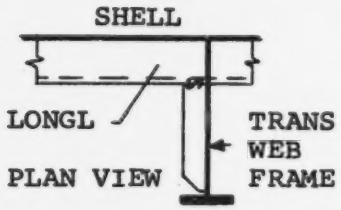
FIGURE 52

PANEL STIFFENER FAILURE ON
WEB FRAME OF A TANKER





KEY TO PHOTO

The photograph shows the connections of a detail 12-C-3 panel stiffener to a shell longitudinal at mid depth of the cargo tank. Encircled by white paint, the crack is in the heat affected zone. Note the stiffener is offset about 1-1/2 inches from alignment with the web of the shell longitudinal.

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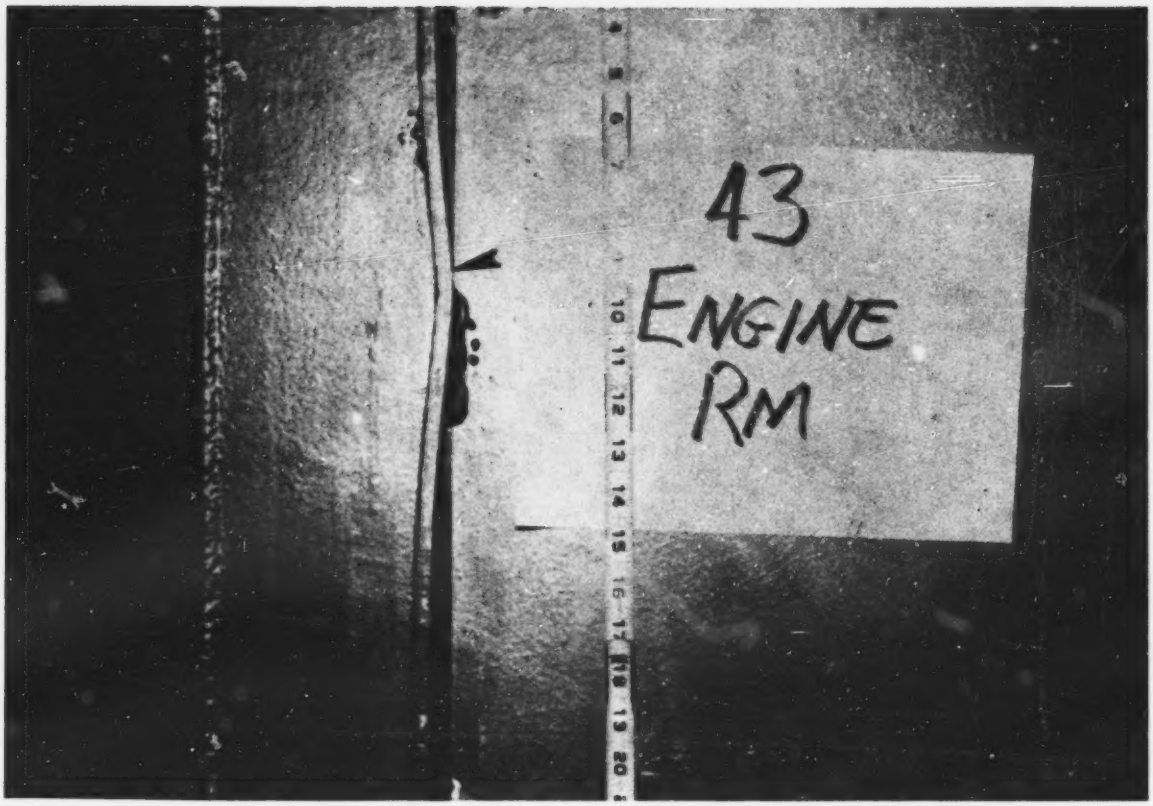
FIGURE 53

BUCKLED PANEL STIFFENER ON A GENERAL CARGO SHIP



The photograph shows the buckled position of a detail 12-C-5 flat bar panel stiffener on a girder web. The 26" x 4" girder was laterally displaced resulting in the buckled panel stiffener.

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FIGURE 54

REINFORCED PANEL STIFFENER
ON A CONTAINERSHIP

The vertical sniped flat bar panel stiffeners are on a transverse hatch side coaming. Reinforcement of the panel stiffeners to alleviate cracks at the ends was by an addition of a flanged plate which makes the detail into a tripping bracket. Visible in the upper right corner of the picture is a horizontal crack in the hatch cover side immediately below two attached container tie down fittings.

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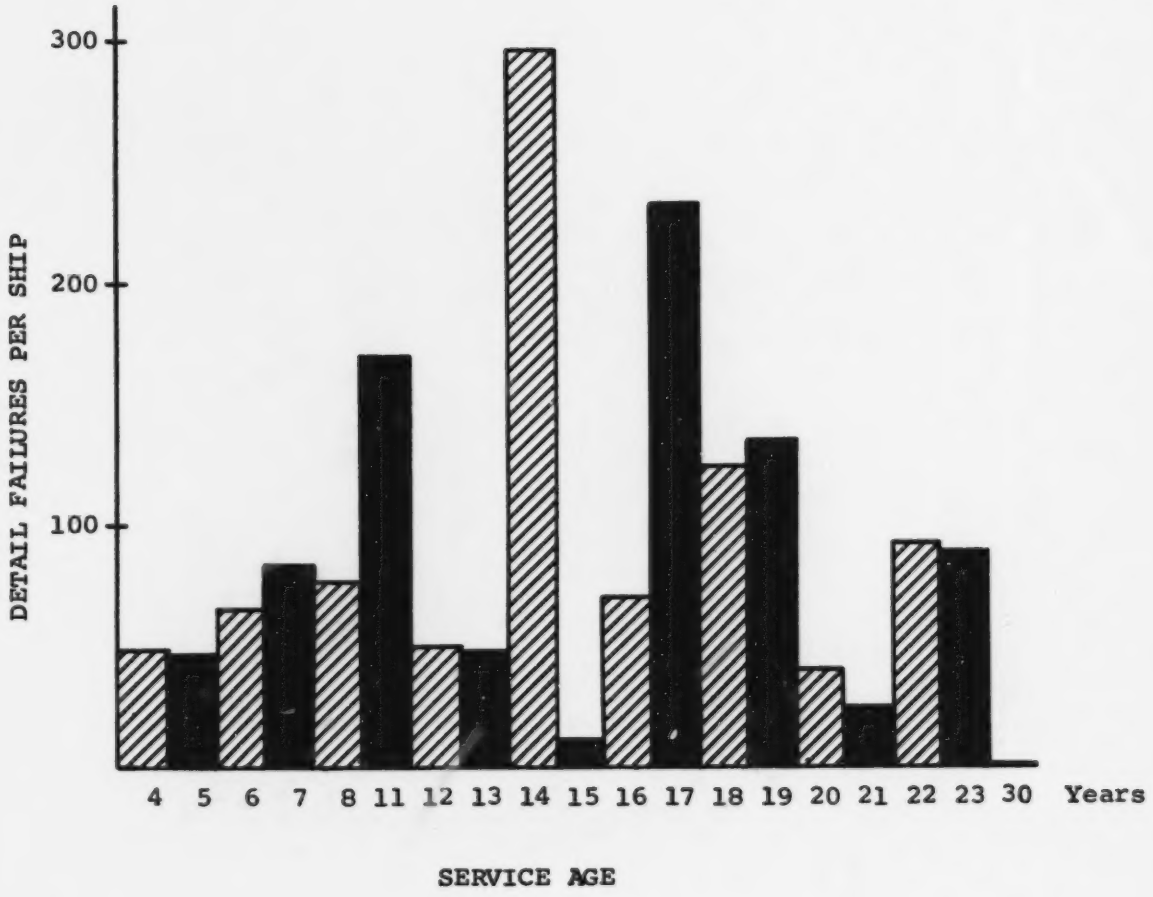
FIGURE 55

SERVICE FAILURE RATE



* Ships of ages 9, 10 and 24 through 29 were not surveyed.

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TABLE 16

SUMMARY OF DATA FROM 50 SHIPS

FAMILY NO.	DETAIL FAMILY NAME	OBSERVED			ESTIMATED		
		No. Details	No. Failures	% Failures	Total No. Details	Total No. Failures	% Failures
1	Beam Bracket	50750	888	1.75	113580	1297	1.14
2	Tripping Bracket	20640	314	1.52	45220	358	.79
3	Non-Tight Collar	16250	28	.17	38040	33	.09
4	Tight Collar	18000	0	0	55760	0	0
5	Gunwale Connection	100	4	4.00	100	4	4.00
6	Knife Edges	0	0	-	0	0	-
7	Miscellaneous Cutouts	252870	646	.26	789710	794	.10
8	Clearance Cutouts	48510	821	1.69	162600	1076	.66
9	Deck Cutouts	6030	12	.20	9660	14	.14
10	Stanchion Ends	6270	98	1.56	7920	112	1.41
11	Stiffener Ends	30760	229	.74	75030	288	.39
12	Panel Stiffeners	40030	267	.67	99590	308	.31
	TOTALS	490210	3307	.67	1397210	4284	.31

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A total of 490,210 details were observed during the overall survey period with a total of 3,307 failures. Eighty-two percent of the observed failures were located in the midship portion of the ship, predominately in structure adjacent to the side shell. The remaining 18% observed failures had a distribution of 10% forward of the cargo spaces and 8% aft of the cargo spaces. Table 17 is a listing of the twenty detail variations that had either the most observed failures or highest percentage of failures. They are listed in two columns of ten each in descending order of participation. The detail variations are identified by their assigned position in the individual families, i.e., the first number(s) is the family number, the letter is the group number and the last number(s) is the variation number.

Figure 56 depicts each detail variation, by family, that had an observed failure. Directly below each sketch is the calculated failure percentage. Failure types and locations are indicated by (+) for a buckle and (-) for a crack.

The appendix of this report includes tabulations of all of the numerical data for each detail variation observed in the survey. These data, in conjunction with photographs and shipboard interviews, were used in the development of the synthesis presented in the report.

CONCLUSIONS AND RECOMMENDATIONS

The data presented in this report were collected from on board inspections of fifty ships of various types. Operating service of these ships ranged from four to thirty years. The service performance of the twelve structural detail families was obtained from visual inspections, interviews with ship personnel, and review of repair specifications.

The twelve structural detail families were found to be 99.33% sound. The remaining 0.67%, however, represents 3,307 observed failures (4,280 estimated). This is an average of sixty-six observed failures per ship (eighty-six estimated).

No conclusions are made for any one of the 553 observed detail variations. Since many of the variations occurred only a few times, the survey data was synthesized by family groups and not ship types. Itemized tabular sheets containing data for each detail variation are included in the appendix to aid the engineer or designer in the selection of detail configurations.

Several of the detail families resulted in damage in the forward shell and forecastle areas of the ship. Damage of this type results from "driving" the ship at high speeds in heavy weather. Interviews with ship personnel indicated that this type of operating condition is necessitated by delivery schedules. With the uncertainty of the slamming loads produced by such conditions, extreme care should be used in the selection and design of all structural connections in the forward areas of the ship.

Fabrication techniques should be used that ensure proper continuity of structural parts and welding so that notches, jagged edges, or under-cut welds will be minimized. Ship owners and operators could

TABLE 17

TOP TEN FAILED DETAILS

RANK	MOST PREVALENT			HIGHEST PERCENTAGE		
	Details Number	No. of Failures	% Failures	Details Number	No. of Failures	% Failures
1	8-D-6	420	4.8	10-B-9	30	100.0
2	7-H-1	224	.8	12-A-7	10	100.0
3	1-C-1	153	2.3	2-C-13	60	60.0
4	2-C-22	124	20.7	10-B-24	6	60.0
5	8-D-5	124	4.6	9-C-2	6	60.0
6	11-A-1	96	1.7	10-C-5	6	60.0
7	7-E-1	94	.6	1-K-4	16	40.0
8	1-C-2	86	2.2	11-C-6	7	35.0
9	12-D-4	80	20.0	1-J-4	16	32.0
10	8-C-2	72	6.7	2-A-9	15	30.0

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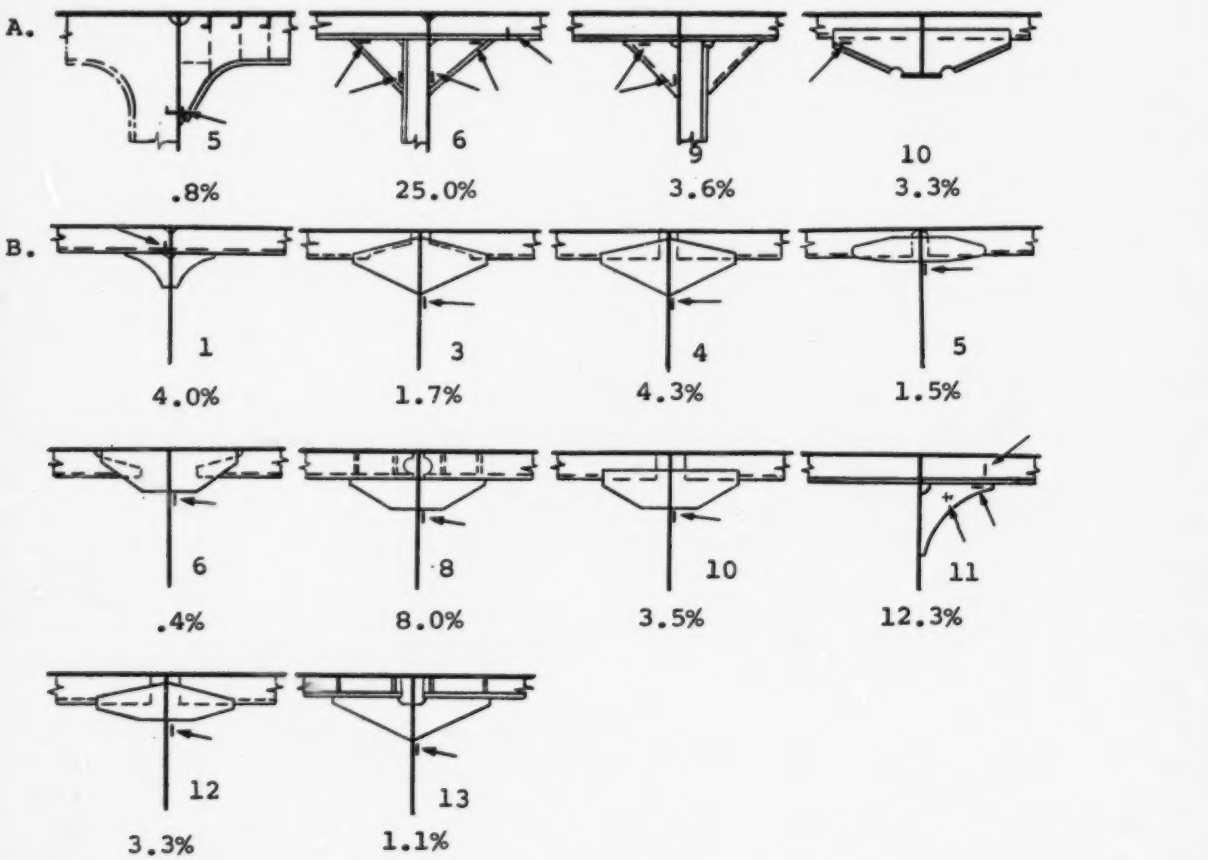
FIGURE 56

DETAIL VARIATIONS WITH OBSERVED FAILURES

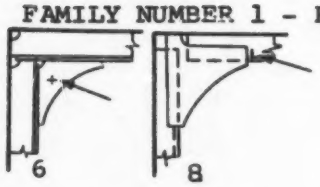
FAMILY NUMBER 1 - BEAM BRACKETS



BEST DOCUMENT AVAILABLE

FAMILY NUMBER 1 - BEAM BRACKETS (Cont'd)

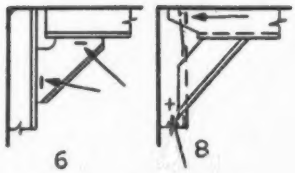
D.



6 — 5.0%

8 — 2.0%

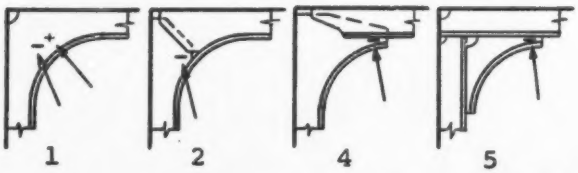
E.



6 — 3.3%

8 — 2.0%

F.



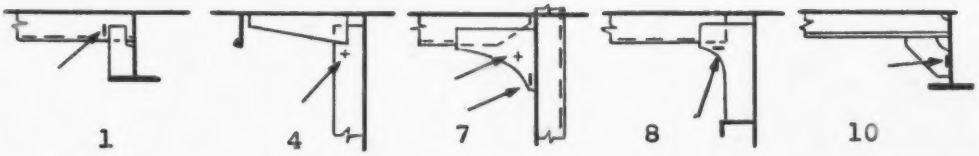
1 — 2.4%

2 — 2.8%

4 — 4.3%

5 — 6.0%

H.



1 — 2.7%

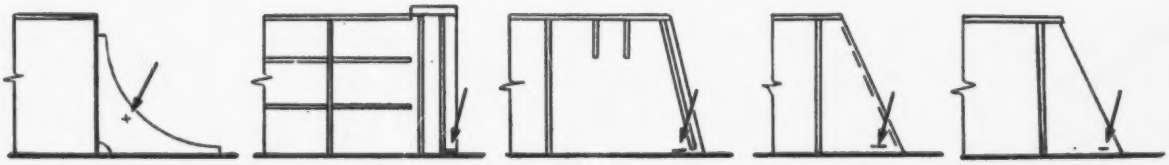
4 — 3.3%

7 — 2.5%

8 — 2.2%

10 — 3.3%

J.



1 — 12.0%

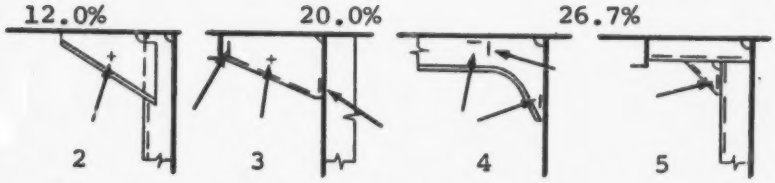
2 — 20.0%

3 — 26.7%

4 — 32.0%

5 — 30.0%

K.

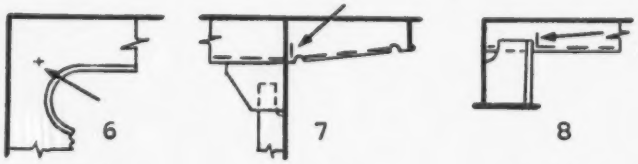


2 — 2.2%

3 — 20.0%

4 — 40.0%

5 — 1.2%

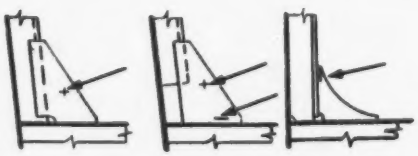


6 — 3.3%

7 — 10.0%

8 — 4.0%

L.

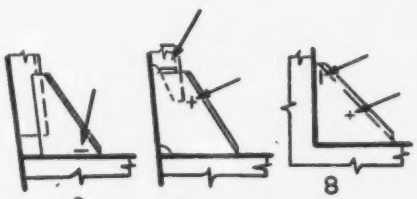


1 — 8.9%

2 — 7.9%

4 — 8.0%

M.



2 — .3%

6 — 4.9%

8 — 1.9%

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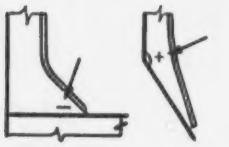
FAMILY NUMBER 1 - BEAM BRACKETS (Cont'd)

N.

1 — 12.5%
5 — 16.2%
7 — 5.0%

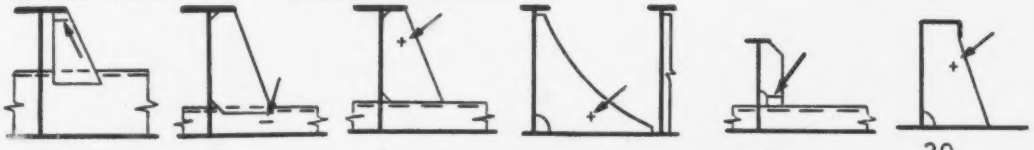
P.



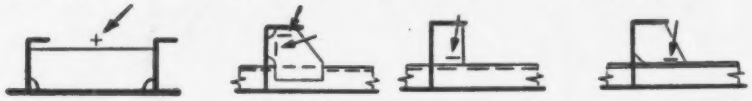
1 — 14.4%
4 — 20.0%

FAMILY NUMBER 2 - TRIPPING BRACKETS

A.



3 — 20.0%
5 — 3.3%
6 — .7%
9 — 30.0%
10 — 1.8%
20 — 10.0%

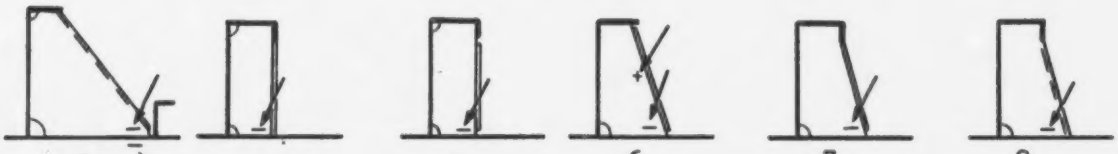


21 — 6.7%
24 — .6%
26 — 1.2%
27 — .9%

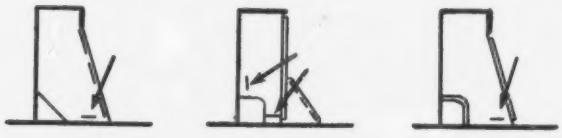
B.

3 — 1.5%
5 — .2%
12 — 2.8%
15 — .6%
18 — 4.0%
19 — 1.1%

C.



2 — 25.0%
4 — 1.8%
5 — 1.2%
6 — 11.4%
7 — 6.8%
8 — 23.1%



12 — 25.0%
13 — 60.0%
14 — 12.9%

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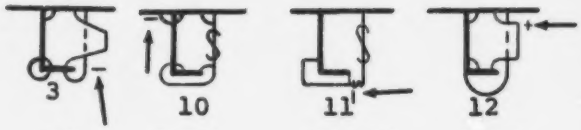
FAMILY NUMBER 3 - NON-TIGHT COLLARS

A.

3 — 2.9%
15 — 3.3%
17 — 3.1%

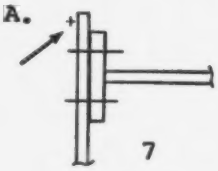
C.



3 — .6%
10 — 6.7%
11 — 10.0%
12 — 1.2%

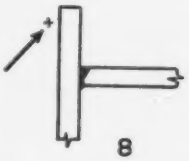
FAMILY NUMBER 5 - GUNWALE CONNECTIONS

A.



7 — 11.1%

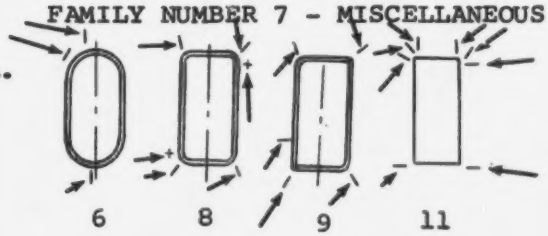
B.



8 — 20.0%

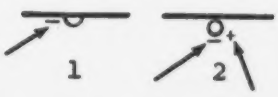
FAMILY NUMBER 7 - MISCELLANEOUS CUTOUTS

A.



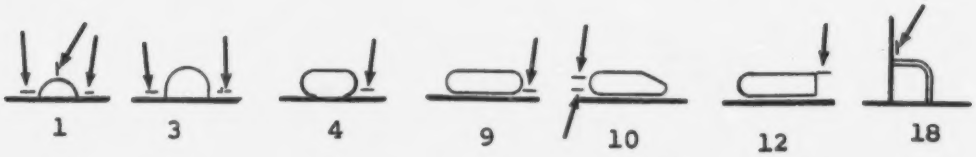
6 — 1.0%
8 — 1.3%
9 — 16.0%
11 — 11.7%

B.



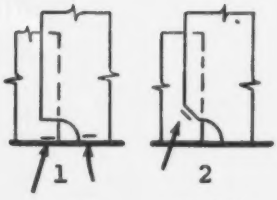
1 — .7%
2 — .3%

C.



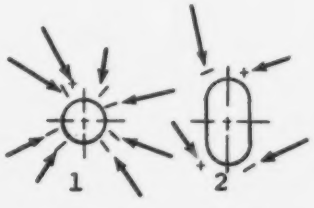
1 — .9%
3 — .3%
4 — .0%
9 — .1%
10 — 20.0%
12 — 20.0%
18 — 2.5%

D.



1 — 1.0%
2 — 7.3%

E.

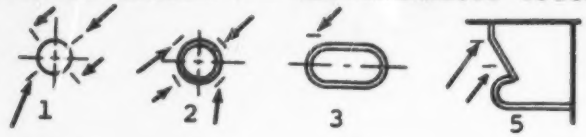


1 — .6%
2 — 5.6%

BEST DOCUMENT AVAILABLE

FAMILY NUMBER 7 - MISCELLANEOUS CUTOUTS (Cont'd)

F.

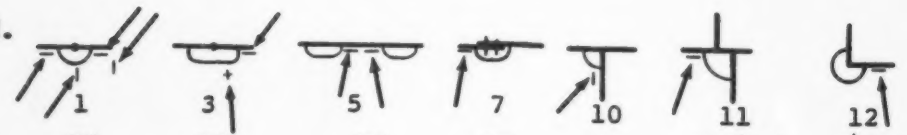


.1% .3% .3% 20.0%

G.

.1%

H.



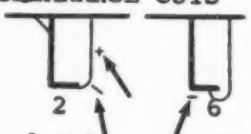
.8% .4% .3% .1% .1% 10.0% 1.5%

FAMILY NUMBER 8 - CLEARANCE CUTS

A.

13.3%

B.

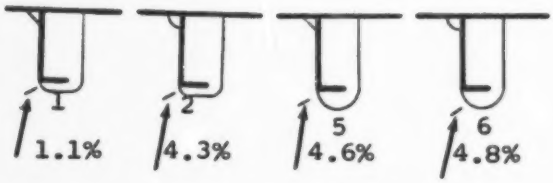


1.0% 1.1%

C.

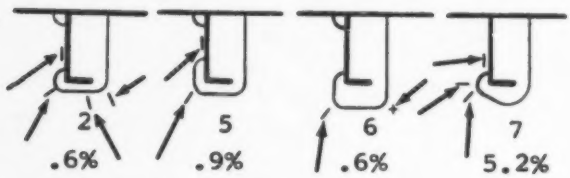
6.7% .1% .3%

D.



1.1% 4.3% 4.6% 4.8%

E.



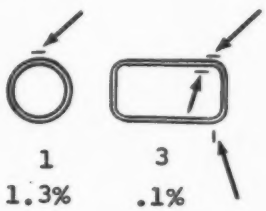
.6% .9% .6% 5.2%

FAMILY NUMBER 9 - DECK CUTOUTS

A.

.3%

B.



1.3% .1%

C.

60.0%

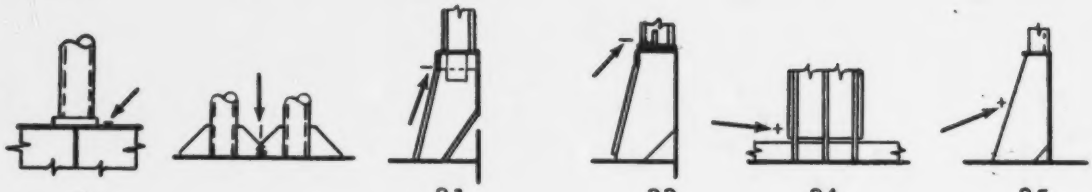
BEST DOCUMENT AVAILABLE

FAMILY NUMBER 10 - STANCHION ENDS

A.

20.0% .2% 10.3%

B.



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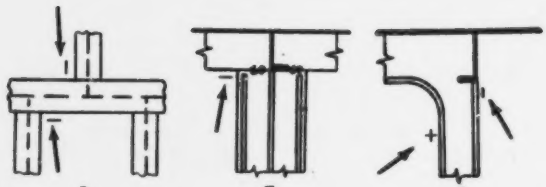

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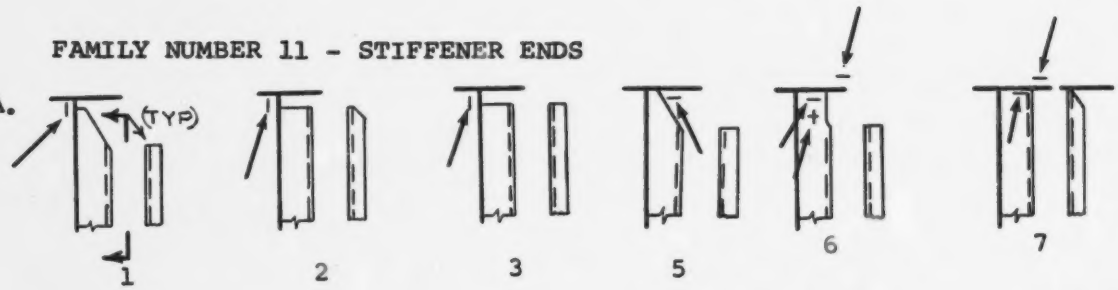
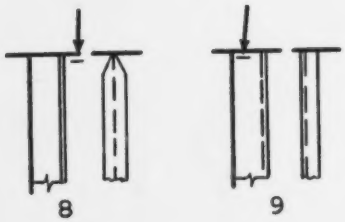
FAMILY NUMBER 11 - STIFFENER ENDS

A.



1.7% .6% .5% 2.5% 6.3% .2%



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FAMILY NUMBER 11 - STIFFENER ENDS (Cont'd)

B.

1 — 2.5%

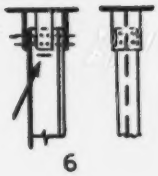
3 — 1.5%

4 — .6%

5 — 1.7%

6 — 10.0%

C.



6 — 35.0

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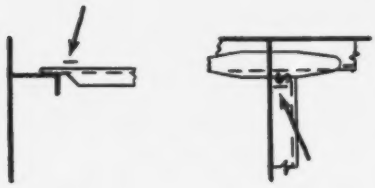
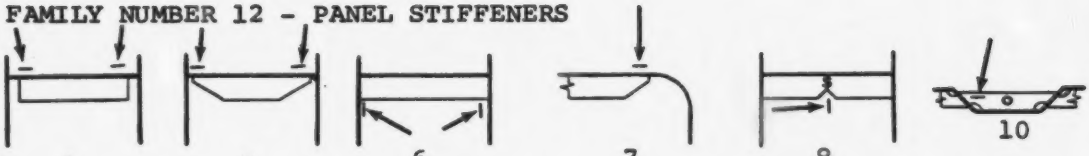


4 — 1.7%

5 — 1.8%

FAMILY NUMBER 12 - PANEL STIFFENERS

A.



1 — 4.2%

3 — .2%

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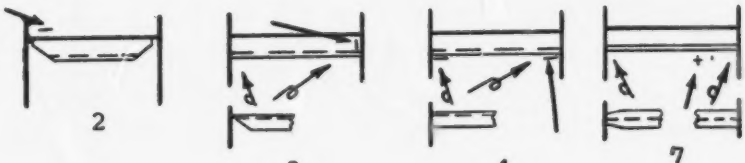
8 — .6%

10 — 1.1%

B.



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3 — .2%

4 — .8%

7 — .4%

C.

1 — 4.3%

3 — .3%

5 — .5%

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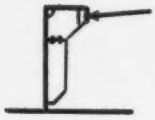
FAMILY NUMBER 12 - PANEL STIFFENERS (Cont'd)

D.

2

3.6%



4

20.0%

E.

2

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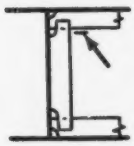
F.



1

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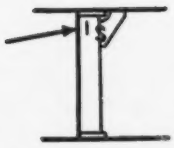

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5

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eliminate some structural failures if they maintained protective coatings on structures subject to the corrosive action of the ocean environment.

The design of openings in "girder-like" members should include secondary bending stress analyses in the areas of the openings to ensure proper sizing of shear areas and face plates. The repetitive type cracks observed in these areas during the survey should be reduced with this type of design procedure.

Each of the twelve families included detail variations which showed no signs of failure. These detail variations should provide guidance in the selection of structural detail configurations in future designs and repairs. It was apparent that many of the detail variations were well designed, and probably the preference of individual design offices, while others were the results of an exigent situation.

The importance of the selection, design, fabrication, and maintenance of structural detail connections cannot be overemphasized. References 8 through 16 contain information on data germane to the subject of structural failures and are included as recommended resource material.

Projects of this type are extremely beneficial in providing "feed-back" data to the engineer and designer who develops a design and never receives the performance data that is needed for future design improvements, growth, and increased confidence. Systematic projects of this type should be a continuing effort and conducted on all areas of the ship with the synthesized data made available to design and repair offices.

It became apparent in the course of this project that ship operators exhibited reluctance in permitting access to their ships when "survey" was suggested since the regulatory bodies also conduct "surveys". It is, therefore, recommended that in future studies the word "performance" be substituted for the word "survey".

The summary of data from 50 ships, Table 16, includes estimates of the total number of details on the ships. These estimates were included to give an indication of the accessibility of all the details on ships undergoing normal maintenance and repairs. Many compartments are inaccessible, loaded with cargo, or outfitted such that details cannot be seen. These estimates were not arrived at by formulas. Since the conditions of each ship were different, the estimates are intuitive based on the surveyor's experience and familiarity with the structural design of the various ship types. In many cases, less than 50% of the details were accessible, it is felt that more ships should be surveyed in an effort to develop a sufficient data bank for conducting statistical analyses.

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ACKNOWLEDGEMENTS

The authors are grateful to the personnel of the shipyards and repair yards who participated in this survey by allowing the surveyors access to their facilities, and to the Supervisor of Shipbuilding personnel for their help and cooperation. A special word of appreciation is extended to the owners and operators who permitted the survey of their ships and provided valuable information during the on board interviews. Also, the authors wish to thank the members of the ad hoc Project Advisory Committee of the National Research Council for giving their time and support to this project.

APPENDIX

Compilation of Performance Data for 553 Observed Structural Detail Variations

This appendix contains a table of failure data arranged by family groups for each of the detail variations observed in the survey. Both observed and estimated results for the various ship types are presented. The "Failure Mode" and "Failure Cause" columns are postulated by the use of appropriate identification numbers listed in "Notes" (C) and (D) at the bottom of each table. A design office or repair facility can use this reference material in selecting the most economical and appropriate configuration for a particular loading condition and structural arrangement.

TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	30		30		50	1-A-1		
	⋈	140		140		360			
	Aft	40		40		90			
Naval	Fwd	20		20		40	1-A-2		
	⋈	110		110		280			
	Aft	30		30		80			
Naval	Fwd	240		240		610	1-A-3		
	⋈	1680		1680		4200			
	Aft	490		490		1220			
Naval	Fwd	120		120		200	1-A-4		
	⋈	510		510		1400			
	Aft	200		200		400			
Miscellaneous	Fwd						1-A-5		
	⋈	40		40		100			
	Aft								
Tanker	Fwd						1-A-5	1	11
	⋈	198	2	200	1.0	520			
	Aft								
Tanker	Fwd						1-A-6	1	8,11,14
	⋈	45	15	60	25.0	130			
	Aft								
Naval	Fwd	50		50		110	1-A-7		
	⋈	270		270		720			
	Aft	90		90		220			
Naval	Fwd	40		40		90	1-A-8		
	⋈	240		240		630			
	Aft	70		70		180			
Tanker	Fwd	20		20		60	1-A-9	1	8,13
	⋈	56	4	60	6.7	160			
	Aft	30		30		40			
General Cargo	Fwd						1-A-10	1	13
	⋈								
	Aft	29	1	30	3.3	50			
Naval	Fwd	30		30		80	1-A-11		
	⋈	90		90		230			
	Aft	20		20		40			
Naval	Fwd						1-B-1		
	⋈	70		70		160			
	Aft								
Tanker	Fwd						1-B-1	1	13
	⋈	26	4	30		50			
	Aft								

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Miscellaneous	Fwd	110		110		300	1-B-2		
	Aft	50		50		100			
Tanker	Fwd						1-B-2		
	Aft	30		30		50			
Tanker	Fwd	39	1	40	2.5	100	1-B-3	1	8
	Aft	20		20		30			
Tanker	Fwd	266	14	280	5.0	700	1-B-4	1	8
	Aft	40		40		100			
Tanker	Fwd	394	6	400	1.5	900	1-B-5	1	8,9,10
	Aft								
Miscellaneous	Fwd	160		160		400	1-B-6		
	Aft								
Tanker	Fwd	1494	6	1500	.4	3800	1-B-6	1	8,9
	Aft	40		40		60			
Bulk Carrier	Fwd	80		80		200	1-B-7		
	Aft								
Tanker	Fwd	515	45	560	8.0	1400	1-B-8	1	8
	Aft								
Tanker	Fwd						1-B-9		
	Aft	150		150		300			
Tanker	Fwd	288	12	300	4.0	700	1-B-10	1	8
	Aft	40		40		100			
Containership	Fwd	40		40		100	1-B-11		
	Aft								
Miscellaneous	Fwd	46	4	50	8.0	100	1-B-11	2	12
	Aft								
Tanker	Fwd	28	12	40	30.0	70	1-B-11	1	13
	Aft								
Tanker	Fwd						1-B-12		
	Aft	58	2	60	3.3	150		1	8
Bulk Carrier	Fwd	49	1	50	2.0	100	1-B-13	1	14
	Aft								
Tanker	Fwd						1-B-13		
	Aft	40		40		100			
Combination Carrier	Fwd	600	1	600	.0	1300	1-C-1	1	15
	Aft	2999		3000		5900			
		150		150		300			
Containership	Fwd	100	150	100	21.4	200	1-C-1	2	12,14
	Aft	550		700		1350			
		110		110		230			

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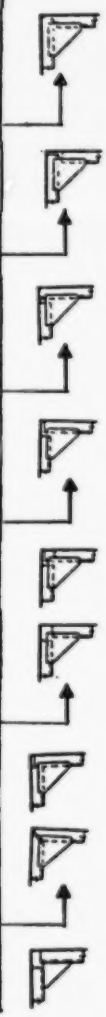
TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	140		140		320			
	⋈	1010		1010		2240	1-C-1		
	Aft	230		230		640			
Tanker	Fwd	198	2	200	1.0	460		2	14
	⋈						1-C-1		
	Aft	400		400		1000			
Containership	Fwd	488	12	500	2.4	1000		2	11,12
	⋈	2590	10	2600	.4	5350	1-C-2	1	10
	Aft	542	58	600	9.7	1250		2	14,11
Tanker	Fwd	114	6	120	5.0	270		2	14
	⋈						1-C-2		
	Aft	60		60		130			
Combination Carrier	Fwd	20		20		40			
	⋈	260		260		400	1-C-3		
	Aft	30		30		50			
Containership	Fwd	48	2	50	4.0	100		2	14
	⋈						1-C-3		
	Aft								
Containership	Fwd	70		70		150			
	⋈	450		450		1000	1-C-4		
	Aft	130		130		250			
General Cargo	Fwd	90		90		200			
	⋈						1-C-4		
	Aft	90		90		200			
Tanker	Fwd	108	2	110	1.8	300		2	14
	⋈						1-C-5		
	Aft	240		240		600			
Containership	Fwd	116	4	120	3.3	300		2	14
	⋈						1-C-6		
	Aft	200		200		500			
Tanker	Fwd	59	1	60	1.7	150		1	15
	⋈						1-C-6		
	Aft	100		100		250			
Miscellaneous	Fwd	80		80		200			
	⋈						1-C-7		
	Aft	40		40		100			
Containership	Fwd	497	3	500	.6	1000		2	14
	⋈	4100		4100		9000	1-C-8		
	Aft	900		900		2000			
General Cargo	Fwd								
	⋈	200	30	230	13.0	500	1-C-8	2	12,14
	Aft								
Bulk Carrier	Fwd	30		30		50			
	⋈	140		140		300	1-C-9		
	Aft	38	2	40	5.0	50		2	15



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

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7. Combined Tension and Shear
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9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-1 DETAIL FAMILY: · BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	20		20		40	1-C-9		
	Mid	100		100		280			
	Aft	40		40		80			
Tanker	Fwd						1-C-9		
	Mid								
	Aft	50		50		100			
General Cargo	Fwd								
	Mid	39	1	40	2.5	100	1-C-10	2	9,14
	Aft								
Containership	Fwd								
	Mid	236	4	240	1.7	500	1-C-11	2	8
	Aft								
Bulk Carrier	Fwd								
	Mid						1-C-12		
	Aft	45		45		100			
Tanker	Fwd								
	Mid						1-C-12		
	Aft	45		45		100			
Containership	Fwd								
	Mid						1-C-13		
	Aft	30		30		50			
Containership	Fwd	20		20		30			
	Mid	158	2	160	1.2	360	1-C-14	2	9,14
	Aft	20		20		30			
Containership	Fwd	136	14	150	9.3	300	1-C-15	2	11,14
	Aft	100		100		200			
Containership	Fwd	96	4	100	4.0	200	1-C-16	2	15
	Aft	190		190		400			
Bulk Carrier	Fwd	100		100		200			
	Mid	300		300		600	1-C-17		
	Aft								
Containership	Fwd	85	5	90	5.6	200			
	Mid	340		340		700	1-C-17	2	15
	Aft	90		90		200			
Tanker	Fwd	9	1	10	10.0	20			
	Mid						1-C-17	2	14,8
	Aft								
Containership	Fwd	50		50		100			
	Mid	300		300		700	1-C-18		
	Aft	90		90		200			
Naval	Fwd	20		20		40			
	Mid	100		100		280	1-C-19		
	Aft	20		20		80			
Combination Carrier	Fwd								
	Mid	120		120		200	1-C-20		
	Aft								
Combination Carrier	Fwd								
	Mid	50		50		100	1-C-21		
	Aft	170		170		300			
Containership	Fwd	76	4	80	5.0	200		2	14
	Mid	400	120	520	23.1	1300	1-C-22	2	(11,12, 14,15)
	Aft								
General Cargo	Fwd								
	Mid						1-C-23		
	Aft	60		60		100			

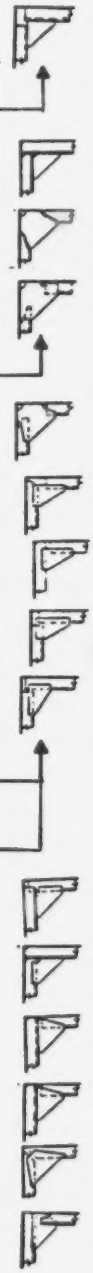

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TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd Aft	111	9	120	7.5	300	1-C-24	2	11
Bulk Carrier	Fwd Aft	140 790 180		140 790 180		300 1600 400	1-D-1		
General Cargo	Fwd Aft	40 310 90		40 310 90		100 700 200	1-D-1		
Miscellaneous	Fwd Aft	20 60 30		20 60 30		40 120 40	1-D-1		
Bulk Carrier	Fwd Aft	50 1000 50		50 1000 50		100 2200 100	1-D-2		
Miscellaneous	Fwd Aft	300 80		300 80		800 200	1-D-2		
Miscellaneous	Fwd Aft	20 120 30		20 120 30		40 280 80	1-D-3		
General Cargo	Fwd Aft	70 20		70 20		150 50	1-D-4		
Bulk Carrier	Fwd Aft	30		30		50	1-D-5		
General Cargo	Fwd Aft	38	2	40	5.0	100	1-D-6	2	9
Miscellaneous	Fwd Aft	40 280 80		40 280 80		100 700 200	1-D-7		
Bulk Carrier	Fwd Aft	49	1	50	2.0	100	1-D-8	1	10
Combination Carrier	Fwd Aft	60		60		100	1-E-1		
Containership	Fwd Aft	40		40		100	1-E-1		
Tanker	Fwd Aft	20 30		20 30		50 50	1-E-1		

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

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14. Heavy Seas
15. Collision
16. Other - See Notes

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*TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	10		10		30	1-E-2		
	Mid	60		60		120			
	Aft	30		30		50			
Combination Carrier	Fwd						1-E-2		
	Mid	60		60		100			
	Aft								
Containership	Fwd	20		20		20	1-E-2		
	Mid								
	Aft								
Tanker	Fwd	30		30		70	1-E-2		
	Mid								
	Aft	40		40		90			
General Cargo	Fwd	20		20		50	1-E-3		
	Mid								
	Aft								
Tanker	Fwd	20		20		40	1-E-3		
	Mid								
	Aft	50		50		80			
General Cargo	Fwd	90		90		200	1-E-4		
	Mid	700		700		1600			
	Aft	130		130		300			
Combination Carrier	Fwd						1-E-5		
	Mid								
	Aft	50		50		100			
Miscellaneous	Fwd	20		20		50	1-E-5		
	Mid								
	Aft	80		80		200			
Tanker	Fwd	20		20		50	1-E-5		
	Mid								
	Aft	80		80		200			
Bulk Carrier	Fwd						1-E-6		
	Mid								
	Aft	20		20		20			
Tanker	Fwd						1-E-6		
	Mid								
	Aft	9	1	10	10.0	10		1	11
Tanker	Fwd						1-E-7		
	Mid	40		40		100			
	Aft	30		30		100			
Containership	Fwd	98	2	100	2.0	220	1-E-8	1,2	5,9
	Mid								
	Aft								
Bulk Carrier	Fwd	20		20		50	1-F-1		
	Mid								
	Aft								
Containership	Fwd	10		10		30	1-F-1		
	Mid	200		200		410			
	Aft	31	9	40	22.5	60		2	13
Tanker	Fwd						1-F-1	1	10
	Mid	442	8	450	1.8	1160			
	Aft								
Tanker	Fwd						1-F-2	1	9,10
	Mid	175	5	180	2.8	400			
	Aft								
Tanker	Fwd	30		30		50	1-F-3		
	Mid								
	Aft								

BEST DOCUMENT AVAILABLE

TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd Aft	47	3	50	6.0	100	1-F-4	1	14
Miscellaneous	Fwd Aft	20		20		50	1-F-4		
Tanker	Fwd Aft	47	3	50	6.0	100	1-F-5	1	14
Naval	Fwd Aft	480 3400 960		480 3400 960		1230 8430 2410	1-G-1		
Naval	Fwd Aft	10 50 30		10 50 30		20 140 40	1-G-2		
Tanker	Fwd Aft	30		30		50	1-G-3		
General Cargo	Fwd Aft	20		20		50	1-G-4		
Naval	Fwd Aft	40		40		100	1-G-4		
Combination Carrier	Fwd Aft	20		20		30	1-G-5		
General Cargo	Fwd Aft	84 130	6	90 130	6.7	200 300	1-H-1	1	14
Combination Carrier	Fwd Aft	50		50		100	1-H-2		
Combination Carrier	Fwd Aft	20 80 20		20 80 20		30 140 40	1-H-3		
Containership	Fwd Aft	29	1	30	3.3	50	1-H-4	2	14
Bulk Carrier	Fwd Aft	90		90		200	1-H-5		
Tanker	Fwd Aft	30		30		50	1-H-6		

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

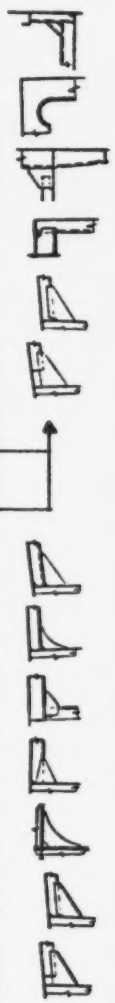
TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	193	7	200	3.5	400	1-H-7	1	14
	Aft	236	4	240	1.7	500		2	12
Bulk Carrier	Fwd	85	5	90	5.5	200	1-H-8	1	14
		100		100		200			
	Aft	40		40		100			
Tanker	Fwd	30		30		60	1-H-9		
	Aft	40		40		90			
General Cargo	Fwd						1-H-10		
	Aft	29	1	30	3.3	50		1	8
Combination Carrier	Fwd	20		20		20	1-H-11		
	Aft	20		20		30			
Tanker	Fwd	20		20		30	1-H-11		
	Aft	20		20		40			
Containership	Fwd								
	Aft	36	4	40	10.0	40	1-J-1	1	8,14
Naval	Fwd								
	Aft	8	2	10	20.0	10	1-J-1	2	13
Combination Carrier	Fwd								
	Aft	16	4	20	20.0	20	1-J-2	1	8
Combination Carrier	Fwd								
	Aft	22	8	30	26.7	30	1-J-3	1	8,11
Bulk Carrier	Fwd								
	Aft	18	12	30	40.0	30	1-J-4	1	8,14
Containership	Fwd								
	Aft	16	4	20	20.0	20	1-J-4	1	8,10
Containership	Fwd								
	Aft	35	15	50	30.0	50	1-J-5	1	8
Bulk Carrier	Fwd								
	Aft	40		40		40	1-J-6		
Containership	Fwd								
	Aft	20		20		20	1-J-6		
Containership	Fwd								
	Aft	90		90		200	1-K-1		
Containership	Fwd								
	Aft	88	2	90	2.2	200	1-K-2	2	8
Tanker	Fwd						1-K-3		
	Aft	8	2	10	20.0	10		1	14
Tanker	Fwd								
	Aft	24	16	40	40.0	70	1-K-4	1	11,13

BEST DOCUMENT AVAILABLE

TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd Aft	168	2	170	1.2	350	1-K-5	1	13
Tanker	Fwd Aft	87	3	90	3.3	200	1-K-6	2	11
Containership	Fwd Aft	9	1	10	10.0	20	1-K-7	1	10
General Cargo	Fwd Aft	112 80	8	120 80	6.7	300 200	1-K-8	1	14
Tanker	Fwd Aft	82	8	90	8.9	200	1-L-1	2	14,15
Containership	Fwd Aft	279 266	41 4	320 270	12.8 1.5	800 600	1-L-2	1,3 2	7,14,15 8,13
General Cargo	Fwd Aft	56	4	60	6.7	100	1-L-2	1	7
Miscellaneous	Fwd Aft	33 20	7	40 20	17.5	60 40	1-L-2	2	15
Tanker	Fwd Aft	50		50		110	1-L-3		
Bulk Carrier	Fwd Aft	46	4	50	8.0	100	1-L-4	1	13
Containership	Fwd Aft	50		50		100	1-L-5		
Containership	Fwd Aft	30		30		50	1-L-6		
Containership	Fwd Aft	80		80		200	1-L-7		
Containership	Fwd Aft	260 200 320		260 200 320		600 600 800	1-M-1		
Containership	Fwd Aft	90 120		90 120		150 250	1-M-2		



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd Aft	60		60		100	1-M-2		
Tanker	Fwd Aft	39	1	40	2.5	50	1-M-2	1	11
Combination Carrier	Fwd Aft	200		200		300	1-M-3		
General Cargo	Fwd Aft	10		10		10	1-M-4		
Tanker	Fwd Aft	30		30		50	1-M-4		
General Cargo	Fwd Aft	50 110		50 110		100 200	1-M-5		
Containership	Fwd Aft	224 109	16 1	240 110	6.7 0.9	600 200	1-M-6	2 1	14 7
General Cargo	Fwd Aft	220		220		500	1-M-7		
Tanker	Fwd Aft	90 160		90 160		200 300	1-M-7		
Combination Carrier	Fwd Aft	148	2	150	1.3	300	1-M-8	2	13
Tanker	Fwd Aft	9	1	10	10.0	10	1-M-8	1	11
Bulk Carrier	Fwd Aft	15	15	30	50.0	40	1-N-1	1	8
Combination Carrier	Fwd Aft	90		90		300	1-N-1		
Containership	Fwd Aft	30		30		50	1-N-2		
Naval	Fwd Aft	10 30 10		10 30 10		10 90 20	1-N-3		
Naval	Fwd Aft	20 180 30		20 180 30		50 380 100	1-N-4		
Bulk Carrier	Fwd Aft	109	21	130	16.2	300	1-N-5	3,4	15
Naval	Fwd Aft	50		50		100	1-N-6		
Naval	Fwd Aft	19	1	20	5.0	30	1-N-7	2	8,12

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TABLE A-1 DETAIL FAMILY: BEAM BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd Aft	40		40		60	1-P-1		
Miscellaneous	Fwd Aft	10		10		20	1-P-1		
Tanker	Fwd Aft	181	39	220	17.7	450	1-P-1	1	6,8,14
Combination Carrier	Fwd Aft	310		310		600	1-P-2		
Miscellaneous	Fwd Aft	50		50		150	1-P-3		
Bulk Carrier	Fwd Aft	24	6	30	20.0	70	1-P-4	3	15

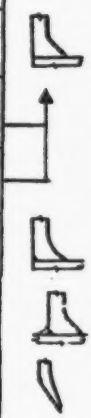


TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd Aft	10 20 20		10 20 20		20 50 30	2-A-1		
Containership	Fwd Aft	20 110 40		20 110 40		30 200 70	2-A-2		
General Cargo	Fwd Aft	10 100 40		10 100 40		30 210 60	2-A-2		
Tanker	Fwd Aft	20 160 30		20 160 30		20 500 40	2-A-2		
General Cargo	Fwd Aft	8	2	10	20.0	10	2-A-3	1	8,12

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

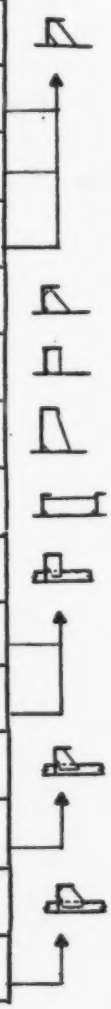
TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Combination Carrier	Fwd	20		20		40	2-A-4		
	Aft	310		310		580			
		100		100		180			
Containership	Fwd	30		30		50	2-A-4		
	Aft								
Tanker	Fwd	30		30		40	2-A-4		
	Aft								
Tanker	Fwd	145	5	150	3.3	250	2-A-5	1	8
	Aft								
Bulk Carrier	Fwd	40		40		80	2-A-6	2	14
	Aft	885	5	890		1790			
		70		70		140			
Combination Carrier	Fwd	50		50		100	2-A-6		
	Aft								
Tanker	Fwd	110		110		230	2-A-6	2	11
	Aft	632	8	640	1.2	1610			
		140		140		360			
Tanker	Fwd	80		80		200	2-A-7		
	Aft								
Containership	Fwd	40		40		80	2-A-8		
	Aft	230		230		600			
		50		50		120			
Bulk Carrier	Fwd	35	15	50	30.0	70	2-A-9	2	15
	Aft								
Containership	Fwd	10		10		20	2-A-10		
	Aft	200		200		400			
		40		40		80			
Tanker	Fwd	10		10		20	2-A-10	1	6,10
	Aft	260	10	270	3.7	580			
		20		20		40			
Containership	Fwd	20		20		30	2-A-11		
	Aft	100		100		210			
		40		40		60			
Containership	Fwd	40		40		90	2-A-12		
	Aft	370		370		750			
		80		80		160			
Naval	Fwd	60		60		100	2-A-13		
	Aft	160		160		440			
		70		70		160			
Tanker	Fwd	20		20		30	2-A-14		
	Aft	70		70		200			
		30		30		70			
Tanker	Fwd	20		20		30	2-A-15		
	Aft								
		30		30		70			
Combination Carrier	Fwd	30		30		50	2-A-16		
	Aft								

BEST DOCUMENT AVAILABLE

TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd ⋈ Aft	140		140		300	2-A-17		
Combination Carrier	Fwd ⋈ Aft	110		110		200	2-A-17		
General Cargo	Fwd ⋈ Aft	20		20		50	2-A-17		
Tanker	Fwd ⋈ Aft	40 80		40 80		100 200	2-A-17		
Combination Carrier	Fwd ⋈ Aft	40		40		100	2-A-18		
Tanker	Fwd ⋈ Aft	110 1200 40		110 1200 40		300 3000 100	2-A-19		
Tanker	Fwd ⋈ Aft	9	1	10	10.0	10	2-A-20	2	15
Combination Carrier	Fwd ⋈ Aft	56	4	60		100	2-A-21	2	15
Containership	Fwd ⋈ Aft	80 150 40		80 150 40		160 350 90	2-A-22		
General Cargo	Fwd ⋈ Aft	10 40 20		10 40 20		20 60 20	2-A-22		
Tanker	Fwd ⋈ Aft	40 60		40 60		90 110	2-A-22		
Containership	Fwd ⋈ Aft	30 20		30 20		60 20	2-A-23		
Miscellaneous	Fwd ⋈ Aft	20		20		20	2-A-23		
Containership	Fwd ⋈ Aft	140 584 190	6	140 590 190	1.0	300 1200 400	2-A-24	1 1 1	13 15 13
Tanker	Fwd ⋈ Aft	30 30		30 30		80 50	2-A-24		



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

SHIP TYPE / LOCATION ON SHIP ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	10		10		20	2-A-25		
	Aft	50		50		80			
General Cargo	Fwd	10		10		20	2-A-26		
	Aft	180		180		340			
		30		30		40			
Tanker	Fwd						2-A-26		
	Aft	106	4	110	3.6	200		1	6,10
Naval	Fwd	10		10		10	2-A-27		
	Aft	30		30		50			
		20		20		40			
Tanker	Fwd						2-A-27		
	Aft	49	1	50	2.0	100		1	13
General Cargo	Fwd	10		10		20	2-A-28		
	Aft	70		70		150			
		20		20		30			
Naval	Fwd	110		110		280	2-A-29		
	Aft	640		640		1600			
		240		240		620			
Bulk Carrier	Fwd	10		10		10	2-B-1		
	Aft	40		40		70			
		10		10		20			
Combination Carrier	Fwd	30		30		50	2-B-1		
	Aft	420		420		860			
		30		30		90			
Tanker	Fwd	20		20		50	2-B-2		
	Aft	600		600		1490			
		40		40		60			
Bulk Carrier	Fwd	10		10		20	2-B-3		
	Aft	260		260		540			
		30		30		40			
Combination Carrier	Fwd	40		40		80	2-B-3	2	13,14
	Aft	476	4	480	.8	900			
		70		70		120			
Tanker	Fwd	20		20		60	2-B-3	2	11,15
	Aft	433	17	450	3.8	1100			
		40		40		110			
Containership	Fwd	20		20		40	2-B-4		
	Aft	200		200		420			
		50		50		80			
Miscellaneous	Fwd	10		10		10	2-B-4		
	Aft	70		70		180			
		10		10		10			
Tanker	Fwd	20		20		50	2-B-4		
	Aft	30		30		50			
Naval	Fwd	60		60		160	2-B-5		
	Aft	310		310		660			
		149	1	150	.7	280		2	13
Naval	Fwd	120		120		400	2-B-6		
	Aft								
Containership	Fwd	40		40		100	2-B-7		
	Aft								

BEST DOCUMENT AVAILABLE

TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Combination Carrier	Fwd	30		30		60	2-B-8		
	▯	100		100		180			
	Aft	90		90		160			
Miscellaneous	Fwd						2-B-8		
	▯	20		20		20			
	Aft								
Combination Carrier	Fwd	20		20		50	2-B-9		
	▯	390		390		750			
	Aft	110		110		200			
Combination Carrier	Fwd	20		20		50	2-B-10		
	▯	180		180		350			
	Aft	60		60		100			
Naval	Fwd	40		40		120	2-B-10		
	▯	230		230		600			
	Aft	90		90		180			
Tanker	Fwd	10		10		20	2-B-11		
	▯	170		170		350			
	Aft	20		20		30			
Bulk Carrier	Fwd						2-B-12		
	▯	30		30		60			
	Aft	30		30		40			
Naval	Fwd	10		10		20	2-B-12		
	▯	30		30		50			
	Aft	20		20		30			
Tanker	Fwd						2-B-12	1	8,13
	▯	821	29	850	3.4	2150			
	Aft	50		50		80			
Tanker	Fwd						2-B-13		
	▯	50		50		110			
	Aft								
Containership	Fwd						2-B-14		
	▯	20		20		50			
	Aft								
Tanker	Fwd	99	1	100	1.0	270	2-B-15	1	15
	▯	20		20		60			
	Aft	40		40		50			
Naval	Fwd	20		20		60	2-B-16		
	▯	140		140		370			
	Aft	50		50		120			
Containership	Fwd						2-B-17		
	▯								
	Aft	10		10		10			
Containership	Fwd						2-B-18	1	8,14
	▯	48	2	50	4.0	100			
	Aft								

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ▯ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd Aft	10 99 20	1	10 100 20	1.7	10 220 20	2-B-19	1	13
Tanker	Fwd Aft	360		360		900	2-C-1		
Tanker	Fwd Aft	30	10	40	25.0	50	2-C-2	1	8
Containership	Fwd Aft	20		20		50	2-C-3		
Combination Carrier	Fwd Aft	69	1	70	1.4	100	2-C-4	1	14
Containership	Fwd Aft	39	1	40	2.5	60	2-C-4	1	14
Containership	Fwd Aft	158	2	160	1.2	200	2-C-5	1	14
Containership	Fwd Aft	106	14	120	11.7	250	2-C-6	1	8,10
Tanker	Fwd Aft	18	2	20		20	2-C-6	2	12
Bulk Carrier	Fwd Aft	250	10	260	3.9	340	2-C-7	1	7,8,10
Containership	Fwd Aft	216	24	240	10.0	300	2-C-7	1	14
Containership	Fwd Aft	200	60	260	23.1	300	2-C-8	1	8,10,14
Bulk Carrier	Fwd Aft	40		40		50	2-C-9		
Bulk Carrier	Fwd Aft	60		60		60	2-C-10		
General Cargo	Fwd Aft	210		210		300	2-C-11		
Containership	Fwd Aft	15	5	20	25.0	20	2-C-12	1	14
General Cargo	Fwd Aft	40	60	100	60.0	100	2-C-13	1	12
General Cargo	Fwd Aft	61	9	70	12.9	80 20	2-C-14	1	11
Naval	Fwd Aft	10 30 10		10 30 10		10 70 20	2-C-15		

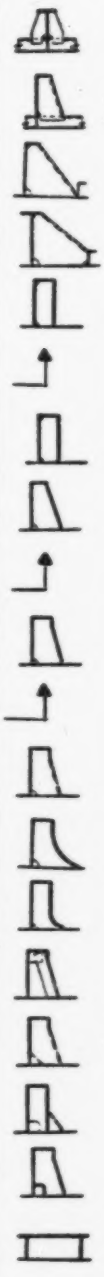

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TABLE A-2 DETAIL FAMILY: TRIPPING BRACKETS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	160		160		470	2-C-16		
	⋈	800		800		2720			
	Aft	310		310		960			
Naval	Fwd	10		10		10	2-C-17		
	⋈	10		10		20			
	Aft	10		10		10			
Naval	Fwd	10		10		10	2-C-18		
	⋈	20		20		30			
	Aft	10		10		10			

TABLE A-3 DETAIL FAMILY: NON-TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Combination Carrier	Fwd	130		130		250	3-A-1		
	⋈	1200		1200		2750			
	Aft	180		180		400			
Bulk Carrier	Fwd	50		50		80	3-A-2		
	⋈	260		260		600			
	Aft	70		70		120			
Containership	Fwd	10		10		30	3-A-2		
	⋈	100		100		200			
	Aft	50		50		100			
Tanker	Fwd	20		20		40	3-A-2		
	⋈	90		90		250			
	Aft	40		40		60			
Containership	Fwd						3-A-3		
	⋈								
	Aft	30		30		50			
Tanker	Fwd	25	5	30	16.7	40	3-A-3	2	15
	⋈	110		110		260			
	Aft								
Containership	Fwd	20		20		50	3-A-4		
	⋈	200		200		400			
	Aft	50		50		80			
Containership	Fwd	90		90		180	3-A-5		
	⋈	470		470		950			
	Aft	120		120		260			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-3 DETAIL FAMILY: NON-TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	10		10		30	3-A-6		
	Aft	10		10		20			
Containership	Fwd	10		10		30	3-A-6		
		110		110		200			
	Aft	30		30		50			
Containership	Fwd	30		30		60	3-A-7		
		200		200		400			
	Aft	50		50		100			
Tanker	Fwd						3-A-8		
	Aft	40		40		50			
Bulk Carrier	Fwd						3-A-9		
	Aft	60		60		100			
Containership	Fwd						3-A-10		
	Aft	40		40		120			
General Cargo	Fwd	10		10		10	3-A-11		
	Aft	10		10		20			
Naval	Fwd	160		160		430	3-A-11		
		1200		1200		3200			
	Aft	320		320		870			
Tanker	Fwd	10		10		20	3-A-11		
	Aft	30		30		40			
Containership	Fwd	40		40		90	3-A-12		
		200		200		400			
	Aft	50		50		100			
Naval	Fwd	20		20		50	3-A-12		
		100		100		250			
	Aft	40		40		100			
Naval	Fwd	20		20		50	3-A-13		
		100		100		250			
	Aft	40		40		100			
Containership	Fwd	70		70		150	3-A-14		
	Aft								
General Cargo	Fwd						3-A-15		
	Aft	58	2	60	3.3	100		1	9
Containership	Fwd						3-A-16		
	Aft	30		30		30			
Containership	Fwd						3-A-17		
	Aft	58	2	60	3.3	100		1	9
General Cargo	Fwd						3-A-17		
	Aft	68	2	70	2.9	100		1	9
Bulk Carrier	Fwd	90		90		200	3-B-1		
		1200		1200		2300			
	Aft	300		300		500			
Combination Carrier	Fwd	140		140		300	3-B-1		
		1200		1200		2100			
	Aft	380		380		600			

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TABLE A-3 DETAIL FAMILY: NON-TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd								
	Aft	40		40		50	3-B-2		
Tanker	Fwd								
	Aft	110		110		200	3-B-3		
Tanker	Fwd	20		20		40	3-B-4		
	Aft	40		40		60			
Tanker	Fwd	160		160		470	3-B-5		
		1200		1200		3100			
	Aft	400		400		1030			
Bulk Carrier	Fwd	30		30		70	3-B-6		
		260		260		550			
	Aft	90		90		180			
Containership	Fwd								
		40		40		100	3-B-7		
	Aft								
Tanker	Fwd								
		80		80		200	3-C-1		
	Aft								
Combination Carrier	Fwd								
	Aft	110		110		200	3-C-2		
Bulk Carrier	Fwd	180		180		400			
		990		990		3000	3-C-3		
	Aft	302	8	310	2.6	950		1	13
Miscellaneous	Fwd	20		20		60			
							3-C-4		
	Aft	20		20		40			
Naval	Fwd	80		80		200			
		300		300		800	3-C-5		
	Aft								
Naval	Fwd	160		160		500			
		700		700		2500	3-C-6		
	Aft	320		320		1000			
Containership	Fwd								
		50		50		100	3-C-7		
	Aft								
Naval	Fwd	30		30		70			
		150		150		400	3-C-8		
	Aft	60		60		130			
Naval	Fwd	20		20		40			
		70		70		120	3-C-9		
	Aft	20		20		60			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-3 DETAIL FAMILY: NON-TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd								
	Aft	56	4	60	6.7	100	3-C-10	1	9
Containership	Fwd	18	2	20	10.0	50	3-C-11	1	9
	Aft								
Miscellaneous	Fwd	57	3	60	5.0	80	3-C-12	2	15
		140		140		300			
	Aft	50		50		120			

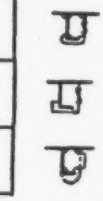

TABLE A-4 DETAIL FAMILY: TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	30		30		60			
		280		280		600	4-A-1		
	Aft	90		90		140			
Combination Carrier	Fwd	210		210		400			
		1100		1100		2900	4-A-1		
	Aft	290		290		700			
Combination Carrier	Fwd	30		30		70			
		220		220		600	4-A-2		
	Aft	70		70		130			
Combination Carrier	Fwd	40		40		100			
		300		300		900	4-A-3		
	Aft	90		90		200			
Tanker	Fwd	80		80		200	4-A-4		
	Aft								
Containership	Fwd	10		10		30			
							4-A-5		
	Aft	120		120		200			
Tanker	Fwd	20		20		50			
		200		200		800	4-A-5		
	Aft	50		50		80			
Bulk Carrier	Fwd	60		60		130			
		350		350		720	4-A-6		
	Aft	90		90		190			
Combination Carrier	Fwd	50		50		140			
		210		210		540	4-A-6		
	Aft	120		120		320			
Containership	Fwd	20		20		50			
							4-A-6		
	Aft	80		80		150			
General Cargo	Fwd	20		20		50			
		120		120		250	4-A-6		
	Aft	50		50		100			
Miscellaneous	Fwd	40		40		100			
		180		180		700	4-A-6		
	Aft	80		80		200			

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TABLE A-4 DETAIL FAMILY: TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	90		90		250	4-A-6		
	⋈								
	Aft	100		100		280			
Bulk Carrier	Fwd						4-A-7		
	⋈	100		100		200			
	Aft								
Containership	Fwd						4-A-7		
	⋈	90		90		200			
	Aft								
Combination Carrier	Fwd	40		40		130	4-A-8		
	⋈	210		210		840			
	Aft	60		60		250			
Combination Carrier	Fwd						4-A-9		
	⋈	130		130		300			
	Aft								
General Cargo	Fwd	30		30		100	4-A-9		
	⋈								
	Aft								
Tanker	Fwd	30		30		50	4-A-10		
	⋈								
	Aft								
Containership	Fwd	90		90		240	4-A-11		
	⋈	680		680		1860			
	Aft	170		170		540			
General Cargo	Fwd	30		30		80	4-A-12		
	⋈	220		220		1030			
	Aft	80		80		200			
Containership	Fwd	30		30		80	4-A-13		
	⋈	180		180		470			
	Aft	60		60		150			
Tanker	Fwd	20		20		50	4-A-13		
	⋈								
	Aft	30		30		70			
Tanker	Fwd	20		20		50	4-A-14		
	⋈								
	Aft	30		30		100			
Combination Carrier	Fwd	10		10		20	4-B-1		
	⋈								
	Aft	40		40		130			
Containership	Fwd						4-B-1		
	⋈								
	Aft	20		20		50			
Containership	Fwd	20		20		60	4-B-2		
	⋈	120		120		420			
	Aft	10		10		20			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-4 DETAIL FAMILY: TIGHT COLLARS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	50		50		170			
	⌶	200		200		660	4-B-3		
	Aft	80		80		240			
Naval	Fwd	300		300		1050			
	⌶	1200		1200		7000	4-B-3		
	Aft	600		600		2100			
Naval	Fwd	20		20		60			
	⌶	100		100		320	4-B-4		
	Aft	30		30		120			
Naval	Fwd	60		60		200			
	⌶	300		300		1400	4-B-5		
	Aft	100		100		400			
Naval	Fwd								
	⌶	30		30		100	4-B-6		
	Aft								
Naval	Fwd	60		60		200			
	⌶	300		300		1400	4-B-7		
	Aft	100		100		400			
Naval	Fwd								
	⌶						4-B-8		
	Aft	20		20		100			
General Cargo	Fwd	10		10		40			
	⌶	40		40		400	4-C-1		
	Aft	30		30		60			
Containership	Fwd								
	⌶	100		100		500	4-C-2		
	Aft								
Containership	Fwd	120		120		200	4-C-3		
	⌶								
	Aft								
Tanker	Fwd								
	⌶						4-C-4		
	Aft	40		40		50			
Tanker	Fwd								
	⌶						4-C-5		
	Aft	40		40		50			
Bulk Carrier	Fwd	10		10		60			
	⌶	300		300		600	4-C-6		
	Aft	50		50		140			
Tanker	Fwd	50		50		120			
	⌶	1000		1000		2300	4-D-1		
	Aft	180		180		280			
Miscellaneous	Fwd								
	⌶	200		200		500	4-D-2		
	Aft								
Tanker	Fwd	20		20		80			
	⌶	2900		2900		8500	4-D-2		
	Aft	240		240		620			
Containership	Fwd								
	⌶	500		500		2000	4-D-3		
	Aft								
Tanker	Fwd								
	⌶	1100		1100		2700	4-D-4		
	Aft	80		80		200			

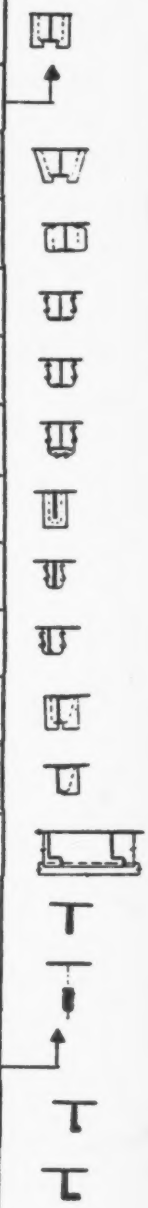

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TABLE A-5 DETAIL FAMILY: GUNWALE CONNECTIONS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd][Aft	4		4		4	5-A-1		
General Cargo	Fwd][Aft	2		2		2	5-A-1		
Tanker	Fwd][Aft	10		10		10	5-A-1		
Containership	Fwd][Aft	2		2		2	5-A-2		
Containership	Fwd][Aft	2		2		2	5-A-3		
Containership	Fwd][Aft	2		2		2	5-A-4		
Naval	Fwd][Aft	4		4		4	5-A-5		
General Cargo	Fwd][Aft	2		2		2	5-A-6		
Bulk Carrier	Fwd][Aft	2		2		2	5-A-7		
Combination Carrier	Fwd][Aft	4		4		4	5-A-7		
General Cargo	Fwd][Aft	2		2		2	5-A-7		
Miscellaneous	Fwd][Aft	2		2		2	5-A-7		
Tanker	Fwd][Aft	6	2	8	25.0	28	5-A-7	2	12,15
Bulk Carrier	Fwd][Aft	2		2		2	5-A-8		

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft,][, and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-5 DETAIL FAMILY: GUNWALE CONNECTIONS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Combination Carrier	Fwd ↓ Aft	2		2		2	5-A-9		
Tanker	Fwd ↓ Aft	2		2		2	5-A-9		
General Cargo	Fwd ↓ Aft	2		2		2	5-A-10		
Naval	Fwd ↓ Aft	2		2		2	5-A-11		
Naval	Fwd ↓ Aft	2		2		2	5-A-12		
Bulk Carrier	Fwd ↓ Aft	2		2		2	5-B-1		
Combination Carrier	Fwd ↓ Aft	4		4		4	5-B-1		
Tanker	Fwd ↓ Aft	4		4		4	5-B-1		
Naval	Fwd ↓ Aft	4		4		4	5-B-2		
General Cargo	Fwd ↓ Aft	2		2		2	5-B-3		
Containership	Fwd ↓ Aft	2		2		2	5-B-4		
Naval	Fwd ↓ Aft	2		2		2	5-B-4		
Containership	Fwd ↓ Aft	4		4		4	5-B-5		
Tanker	Fwd ↓ Aft	2		2		2	5-B-5		
Containership	Fwd ↓ Aft	2		2		2	5-B-6		
Naval	Fwd ↓ Aft	2		2		2	5-B-6		
Containership	Fwd ↓ Aft	2		2		2	5-B-7		
Bulk Carrier	Fwd ↓ Aft	2		2		2	5-B-8		
Containership	Fwd ↓ Aft	4		4		4	5-B-8		

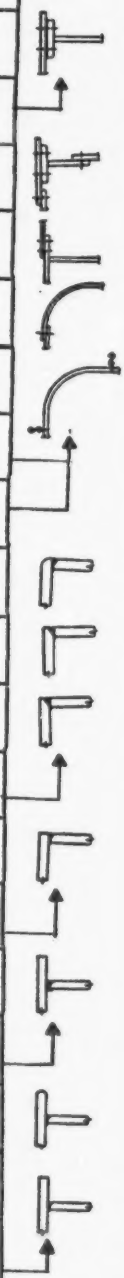

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TABLE A-5 DETAIL FAMILY: GUNWALE CONNECTIONS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Miscellaneous	Fwd ⋈ Aft	0	2	2	100.0	2	5-B-8	2	12,15
Tanker	Fwd ⋈ Aft	2		2		2	5-B-8		

TABLE A-6 DETAIL FAMILY: KNIFE EDGES

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd ⋈ Aft								
Combination Carrier	Fwd ⋈ Aft								
Containership	Fwd ⋈ Aft		NO KNIFE EDGE CROSSINGS OBSERVED IN THE SURVEY				6		
General Cargo	Fwd ⋈ Aft								
Miscellaneous	Fwd ⋈ Aft								
Naval	Fwd ⋈ Aft								
Tanker	Fwd ⋈ Aft								
TOTALS		0	0	0	0	0	0	0	0

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	10		10		50	7-A-1		
	∥	80		80		300			
	Aft	10		10		50			
Containership	Fwd	50		50		190	7-A-1		
	∥	60		60		200			
	Aft	20		20		60			
Tanker	Fwd	10		10		40	7-A-1		
	∥	40		40		120			
	Aft	10		10		40			
Naval	Fwd	30		30		100	7-A-2		
	∥	90		90		300			
	Aft	60		60		200			
Bulk Carrier	Fwd	20		20		50	7-A-3		
	∥	120		120		450			
	Aft	30		30		100			
Containership	Fwd	90		90		300	7-A-3		
	∥	450		450		1600			
	Aft	90		90		300			
Naval	Fwd	60		60		200	7-A-3		
	∥	450		450		1500			
	Aft	100		100		500			
Tanker	Fwd	10		10		40	7-A-3		
	∥	120		120		500			
	Aft	20		20		60			
Combination Carrier	Fwd	20		20		50	7-A-4		
	∥	70		70		180			
	Aft	30		30		70			
Containership	Fwd	10		10		20	7-A-4		
	∥	30		30		90			
	Aft	10		10		40			
Bulk Carrier	Fwd	10		10		10	7-A-5		
	∥								
	Aft	10		10		10			
Containership	Fwd	10		10		30	7-A-5		
	∥								
	Aft	10		10		40			
Naval	Fwd	10		10		10	7-A-5		
	∥	10		10		30			
	Aft	10		10		10			
Bulk Carrier	Fwd	10		10		20	7-A-6		
	∥	10		10		10			
	Aft	10		10		20			
Containership	Fwd	40		40		60	7-A-6	1	7,14
	∥	68	2	70	2.9	140			
	Aft	40		40		60			
Tanker	Fwd	10		10		20	7-A-6		
	∥								
	Aft	20		20		30			
Bulk Carrier	Fwd	10		10		10	7-A-7		
	∥								
	Aft	10		10		10			
Containership	Fwd	20		20		30	7-A-7		
	∥								
	Aft	30		30		40			

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	30		30		50			
	⋈	10		10		20	7-A-8		
	Aft	30		30		50			
Combination Carrier	Fwd	20		20		30			
	⋈	20		20		40	7-A-8		
	Aft	30		30		60			
Containership	Fwd	20		20		40			
	⋈	64	6	70	8.6	160	7-A-8	1	7,14
	Aft	40		40		70			
General Cargo	Fwd	10		10		20			
	⋈	10		10		10	7-A-8		
	Aft	20		20		50			
Miscellaneous	Fwd	10		10		10			
	⋈	10		10		20	7-A-8		
	Aft	20		20		30			
Naval	Fwd	30		30		110			
	⋈	175	5	180	2.8	630	7-A-8	4	14,16
	Aft	40		40		180			
Tanker	Fwd	30		30		90			
	⋈	150		150		200	7-A-8		
	Aft	60		60		220			
General Cargo	Fwd								
	⋈	32	8	40	20.0	40	7-A-9	1	7,8,14
	Aft	10		10		10			
Containership	Fwd	10		10		20			
	⋈						7-A-10		
	Aft	10		10		20			
Tanker	Fwd	20		20		30			
	⋈						7-A-10		
	Aft	20		20		30			
Combination Carrier	Fwd								
	⋈	30		30		40	7-A-11		
	Aft								
Naval	Fwd								
	⋈	6	4	10	40.0	10	7-A-11	1	7,8
	Aft								
Tanker	Fwd	17	3	20	15.0	20	7-A-11	1	7,8,9
	⋈								
	Aft								
Combination Carrier	Fwd	10		10		20			
	⋈	60		60		110	7-A-12		
	Aft	30		30		50			
Containership	Fwd	30		30		50			
	⋈	70		70		180	7-A-12		
	Aft	50		50		70			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	10		10		10	7-A-12		
	Aft	10		10		10			
Tanker	Fwd	10		10		10	7-A-12		
	Aft	10		10		10			
Containership	Fwd	50		50		100	7-B-1	1	9,14
		92	8	100	8.0	700			
	Aft	100		100		200			
General Cargo	Fwd	40		40		100	7-B-1		
		100		100		700			
	Aft	90		90		200			
Tanker	Fwd	30		30		100	7-B-1		
		600		600		2900			
	Aft	120		120		400			
Bulk Carrier	Fwd	70		70		200	7-B-2		
		700		700		3500			
	Aft	200		200		500			
Combination Carrier	Fwd	100		100		200	7-B-2		
		900		900		1500			
	Aft	200		200		300			
Containership	Fwd	150		150		300	7-B-2		
		1000		1000		3300			
	Aft	300		300		600			
General Cargo	Fwd	60		60		100	7-B-2		
		200		200		1000			
	Aft	100		100		200			
Naval	Fwd	70		70		100	7-B-2	1,2	11,16
		1200	20	1220	1.6	2700			
	Aft	80		80		200			
Tanker	Fwd	70		70		100	7-B-2		
		500		500		800			
	Aft	50		50		100			
Bulk Carrier	Fwd	30		30		100	7-B-3		
		400		400		1700			
	Aft	150		150		200			
Containership	Fwd	40		40		100	7-B-3		
		80		80		300			
	Aft	70		70		100			
Miscellaneous	Fwd	120		120		200	7-B-3		
		1300		1300		4400			
	Aft	300		300		400			
Naval	Fwd	120		120		200	7-B-3		
		600		600		1400			
	Aft	220		220		400			
Tanker	Fwd	80		80		300	7-B-3		
		5400		5400		10800			
	Aft	400		400		600			
Containership	Fwd	300		300		400	7-B-4		
	Aft								

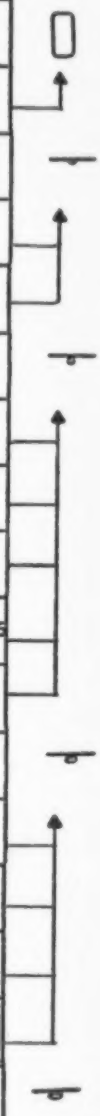

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	40		40		200	7-C-1		
	⋈	100		100		600			
	Aft	70		70		200			
Combination Carrier	Fwd	80		80		200	7-C-1		
	⋈	60		60		600			
	Aft	90		90		200			
Containership	Fwd	90		90		200	7-C-1	1	14
	⋈	680	20	700	2.9	2900			
	Aft	110		110		300			
General Cargo	Fwd	70		70		100	7-C-1		
	⋈	400		400		2700			
	Aft	74	16	90	17.8	200		1	9
Miscellaneous	Fwd	60		60		100	7-C-1		
	⋈	80		80		400			
	Aft	60		60		100			
Naval	Fwd	80		80		100	7-C-1		
	⋈	200		200		300			
	Aft	60		60		100			
Tanker	Fwd	90		90		200	7-C-1	1	8
	⋈	2586	14	2600	.5	4500			
	Aft	200		200		400			
Containership	Fwd	20		20		60	7-C-2		
	⋈	100		100		480			
	Aft	20		20		60			
Miscellaneous	Fwd	20		20		60	7-C-2		
	⋈								
	Aft	20		20		40			
Combination Carrier	Fwd	210		210		600	7-C-3		
	⋈	900		900		7400			
	Aft	180		180		600			
Containership	Fwd	70		70		150	7-C-3	1	11
	⋈	490	10	500	2.0	1750			
	Aft	68	2	70	2.9	150		1	11
General Cargo	Fwd						7-C-3		
	⋈								
	Aft	80		80		150			
Tanker	Fwd	90		90		200	7-C-3		
	⋈	1600		1600		2600			
	Aft	90		90		200			
Containership	Fwd						7-C-4		
	⋈	199	1	200	.5	300		1	11,14
	Aft								
Naval	Fwd	200		200		400	7-C-4		
	⋈	2000		2000		4800			
	Aft	400		400		800			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd Aft	150		150		200	7-C-5		
General Cargo	Fwd Aft	40 20		40 20		50 20	7-C-6		
Combination Carrier	Fwd Aft	70 110 60		70 110 60		200 400 200	7-C-7		
Miscellaneous	Fwd Aft	20 50		20 50		50 100	7-C-7		
Containership	Fwd Aft	30 150		30 150		50 200	7-C-8		
General Cargo	Fwd Aft	20 20		20 20		40 60	7-C-8		
Bulk Carrier	Fwd Aft	70 3000 120		70 3000 120		300 9000 700	7-C-9		
Containership	Fwd Aft	80		80		100	7-C-9		
Naval	Fwd Aft	96 1491 196	4 9 4	100 1500 200	4.0 .7 2.0	300 2100 600	7-C-9	1 1 1	11 11 15
Tanker	Fwd Aft	400 16000 1000		400 16000 1000		1000 27800 2000	7-C-9		
Containership	Fwd Aft	8	2	10	20.0	10	7-C-10	1	8,9
Combination Carrier	Fwd Aft	10		10		10	7-C-11		
Containership	Fwd Aft	20		20		20	7-C-11		
General Cargo	Fwd Aft	10		10		10	7-C-11		
Combination Carrier	Fwd Aft	8	2	10	20.0	10	7-C-12	1	8
Containership	Fwd Aft	70		70		100	7-C-13		
Naval	Fwd Aft	800 2000 1100		800 2000 1100		1200 8000 2300	7-C-13		
Naval	Fwd Aft	40 30		40 30		200 200	7-C-14		

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd								
	⋈								
	Aft	40		40		60	7-C-15		
Combination Carrier	Fwd								
	⋈								
	Aft	60		60		80	7-C-15		
Containership	Fwd	20		20		40			
	⋈						7-C-15		
	Aft	180		180		300			
General Cargo	Fwd	10		10		20			
	⋈						7-C-15		
	Aft	40		40		80			
Miscellaneous	Fwd	10		10		20			
	⋈	30		30		50	7-C-15		
	Aft	20		20		50			
Naval	Fwd	10		10		50			
	⋈	20		20		80	7-C-15		
	Aft	10		10		50			
Tanker	Fwd	300		300		1020			
	⋈	8000		8000		14000	7-C-15		
	Aft	800		800		2000			
Containership	Fwd	40		40		50			
	⋈	300		300		350	7-C-16		
	Aft	80		80		100			
Containership	Fwd								
	⋈	300		300		400	7-C-17		
	Aft	80		80		100			
Naval	Fwd								
	⋈	70		70		100	7-C-17		
	Aft								
Naval	Fwd								
	⋈	78	2	80	2.5	100	7-C-18	1	10
	Aft								
Naval	Fwd								
	⋈	60		60		80	7-C-19		
	Aft	10		10		20			
Containership	Fwd	20		20		40			
	⋈	59	1	60	1.7	300	7-D-1	1	14
	Aft	50		50		60			
Tanker	Fwd	10		10		30			
	⋈	118	2	120	1.7	240	7-D-1	1	14
	Aft	40		40		60			
Bulk Carrier	Fwd	20		20		40			
	⋈	80		80		200	7-D-2		
	Aft	104	16	120	13.3	160		1	9,10,13

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

SHIP TYPE / LOCATION ON SHIP		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	40		40		100	7-D-3		
	Aft	60		60		100			
Bulk Carrier	Fwd	10		10		20	7-D-4		
		20		20		50			
	Aft	10		10		20			
Containership	Fwd	20		20		80	7-D-4		
		30		30		170			
	Aft	30		30		80			
General Cargo	Fwd	50		50		180	7-D-4		
	Aft	80		80		200			
Tanker	Fwd	40		40		100	7-D-5		
		1200		1200		2000			
	Aft	80		80		160			
Bulk Carrier	Fwd	50		50		140	7-E-1		
		200		200		700			
	Aft	180		180		340			
Combination Carrier	Fwd	40		40		100	7-E-1		
		1200		1200		2000			
	Aft	120		120		200			
Containership	Fwd	80		80		200	7-E-1	1	7,14
		396	4	400	1.0	1600			
	Aft	300		300		500			
Miscellaneous	Fwd	70		70		200	7-E-1		
		200		200		1000			
	Aft	170		170		300			
Naval	Fwd	800		800		2000	7-E-1		
		5000		5000		16000			
	Aft	1200		1200		4000			
Tanker	Fwd	140		140		600	7-E-1	1	8,16
		5410	90	5500	1.6	11000			
	Aft	700		700		1200			
Bulk Carrier	Fwd	20		20		40	7-E-2		
		40		40		120			
	Aft	40		40		60			
Combination Carrier	Fwd	20		20		40	7-E-2	2,3	8,14
		435	65	500	13.0	800			
	Aft	30		30		70			
Containership	Fwd	20		20		60	7-E-2		
		100		100		360			
	Aft	30		30		80			
Tanker	Fwd	20		20		60	7-E-2		
		300		300		500			
	Aft	40		40		100			
Bulk Carrier	Fwd	20		20		50	7-F-1		
	Aft	50		50		100			
Combination Carrier	Fwd	20		20		50	7-F-1		
		60		60		200			
	Aft	40		40		100			
Containership	Fwd	30		30		80	7-F-1		
		150		150		500			
	Aft	120		120		270			
General Cargo	Fwd	20		20		40	7-F-1		
		60		60		300			
	Aft	60		60		180			

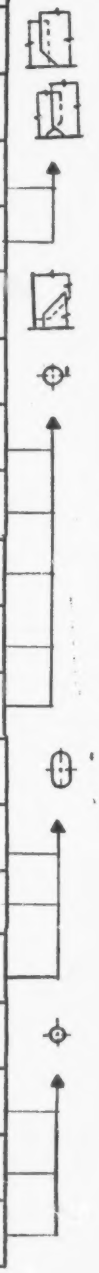

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Miscellaneous	Fwd	10		10		20	7-F-1		
	⋈	60		60		150			
	Aft	40		40		60			
Naval	Fwd	10		10		50	7-F-1		
	⋈	80		80		300			
	Aft	60		60		100			
Tanker	Fwd	10		10		50	7-F-1		
	⋈	220		220		400			
	Aft	159	1	160	.6	250		1	8,9
Bulk Carrier	Fwd	10		10		20	7-F-2		
	⋈	50		50		180			
	Aft	50		50		100			
Combination Carrier	Fwd	20		20		50	7-F-2		
	⋈	150		150		250			
	Aft	60		60		150			
Containership	Fwd	20		20		50	7-F-2		
	⋈	80		80		400			
	Aft	115	5	120	4.2	200		1	10
General Cargo	Fwd	10		10		30	7-F-2		
	⋈	70		70		300			
	Aft	80		80		150			
Miscellaneous	Fwd	10		10		20	7-F-2		
	⋈	90		90		200			
	Aft	40		40		80			
Naval	Fwd	20		20		60	7-F-2		
	⋈	600		600		1400			
	Aft	90		90		300			
Tanker	Fwd	20		20		60	7-F-2		
	⋈	120		120		300			
	Aft	140		140		300			
Bulk Carrier	Fwd	10		10		20	7-F-3		
	⋈	40		40		90			
	Aft	20		20		40			
Combination Carrier	Fwd	10		10		30	7-F-3		
	⋈	30		30		90			
	Aft	40		40		80			
Containership	Fwd	20		20		40	7-F-3		
	⋈	30		30		110			
	Aft	50		50		100			
General Cargo	Fwd						7-F-3		
	⋈	20		20		30			
	Aft	20		20		40			
Miscellaneous	Fwd						7-F-3		
	⋈	10		10		20			
	Aft	10		10		30			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS .

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	20		20		60			
	Aft	200		200		720	7-F-3		
		50		50		160			
Tanker	Fwd	10		10		40			
	Aft	50		50		120	7-F-3		
		38	2	40	5.0	90		1	10
General Cargo	Fwd								
	Aft	10		10		10	7-F-4		
Tanker	Fwd								
	Aft	8	2	10	20.0	10	7-F-5	1	8,9
Containership	Fwd								
	Aft	30		30		100	7-F-6		
General Cargo	Fwd								
	Aft	10		10		20	7-F-6		
Miscellaneous	Fwd								
	Aft	10		10		20	7-F-6		
Naval	Fwd	50		50		200	7-F-6		
	Aft	50		50		200			
Tanker	Fwd								
	Aft	30		30		100	7-F-6		
Bulk Carrier	Fwd	20		20		40	7-G-1		
	Aft	40		40		160			
Combination Carrier	Fwd	10		10		30	7-G-1		
	Aft	40		40		150			
Containership	Fwd	20		20		80	7-G-1		
	Aft	60		60		240			
General Cargo	Fwd	10		10		20	7-G-1		
	Aft	20		20		40			
Miscellaneous	Fwd	10		10		20	7-G-1		
	Aft	20		20		30			
Naval	Fwd	100		100		300			
	Aft	200		200		900	7-G-1		
		200		200		900			
Tanker	Fwd	150		150		200	7-G-1		
	Aft	200		200		600			
Bulk Carrier	Fwd	10		10		40	7-G-2		
	Aft	50		50		110			
Combination Carrier	Fwd	150		150		800	7-G-2		
	Aft	250		250		700			
Containership	Fwd	50		50		250	7-G-2		
	Aft	90		90		250			

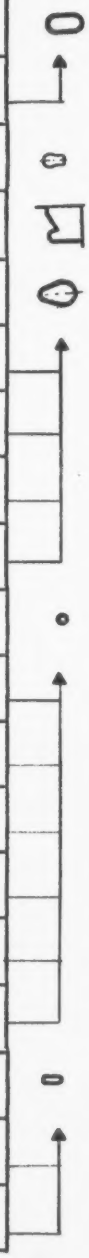

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

SHIP TYPE / LOCATION ON SHIP		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	10		10		60	7-G-2		
	⋈								
	Aft	30		30		70			
Miscellaneous	Fwd	40		40		150	7-G-2		
	⋈								
	Aft	40		40		100			
Naval	Fwd	60		60		200	7-G-2		
	⋈	200		200		700			
	Aft	220		220		700			
Tanker	Fwd	10		10		80	7-G-2		
	⋈								
	Aft	60		60		100			
Bulk Carrier	Fwd	20		20		40	7-G-3		
	⋈	110		110		460			
	Aft	300		300		700			
Combination Carrier	Fwd	30		30		100	7-G-3		
	⋈	200		200		800			
	Aft	600		600		1400			
Containership	Fwd	40		40		150	7-G-3	1	7,14
	⋈	159	1	160	.6	700			
	Aft	500		500		1100			
General Cargo	Fwd	20		20		50	7-G-3		
	⋈	30		30		130			
	Aft	80		80		200			
Miscellaneous	Fwd	10		10		20	7-G-3		
	⋈	30		30		60			
	Aft	70		70		120			
Naval	Fwd	500		500		1600	7-G-3		
	⋈	1800		1800		5000			
	Aft	2197	3	2200	.1	5600		1	7,8
Tanker	Fwd	50		50		170	7-G-3		
	⋈	200		200		400			
	Aft	299	1	300	.3	800		1	10
Containership	Fwd	20		20		30	7-G-4		
	⋈								
	Aft								
Bulk Carrier	Fwd	10		10		20	7-G-5		
	⋈	20		20		60			
	Aft	30		30		60			
Combination Carrier	Fwd						7-G-5		
	⋈								
	Aft	20		20		40			
Containership	Fwd						7-G-5		
	⋈								
	Aft	80		80		200			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd								
	Aft	20		20		40	7-G-5		
Miscellaneous	Fwd								
	Aft	20		20		50	7-G-5		
Tanker	Fwd								
	Aft	60		60		120	7-G-5		
Bulk Carrier	Fwd	300		300		600			
		1496	4	1500	.3	4800	7-H-1	1	9,14
	Aft	600		600		1400			
Combination Carrier	Fwd	366	34	400	8.5	900		1	8,10,15
		1878	22	1900	1.1	6000	7-H-1	1	10,13,15
	Aft	894	6	900	.7	1600		1	10,11
Containership	Fwd	271	29	300	9.7	1000		1	14,15
		3965	35	4000	.9	18000	7-H-1	1	9,10,14
	Aft	884	16	900	1.8	2440		1	9,10,14
General Cargo	Fwd	900		900		2000			
		1960	40	2000	2.0	9000	7-H-1	1	14,15
	Aft	1300		1300		3000			
Miscellaneous	Fwd	300		300		700			
		1500		1500		4500	7-H-1		
	Aft	400		400		1000			
Naval	Fwd	60		60		200			
		797	3	800	.4	1600	7-H-1	1	15
	Aft	200		200		300			
Tanker	Fwd	597	3	600	.5	2000		1	5,15
		6468	32	6500	.5	12000	7-H-1	1	5,7,8,9
	Aft	1700		1700		3700			
Combination Carrier	Fwd	120		120		300			
		700		700		2100	7-H-2		
	Aft	200		200		600			
Naval	Fwd	100		100		500			
		900		900		3500	7-H-2		
	Aft	300		300		1000			
Containership	Fwd	100		100		400			
		792	8	800	1.0	3300	7-H-3	1	14
	Aft	200		200		800			
Naval	Fwd	200		200		600			
		1200		1200		3800	7-H-3		
	Aft	198	2	200	1.0	800		1,2	15
Tanker	Fwd	20		20		50			
		30		30		100	7-H-3		
	Aft	20		20		50			
Tanker	Fwd								
		1200		1200		2000	7-H-4		
	Aft								
Bulk Carrier	Fwd	260	40	300	13.3	2000		1	5,14,15
		4800		4800		24000	7-H-5		
	Aft	784	16	800	2.0	4000		1	14
Containership	Fwd	600		600		3000			
		2600		2600		13000	7-H-5		
	Aft	1200		1200		6000			
Miscellaneous	Fwd	600		600		3000			
		2600		2600		13000	7-H-5		
	Aft	1200		1200		6000			

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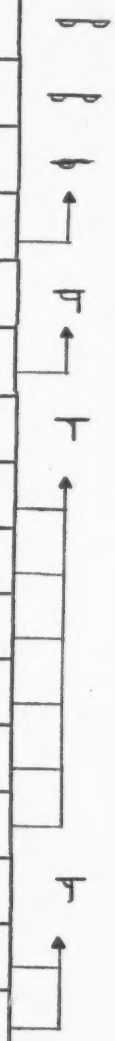
TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	60		60		300	7-H-5		
	⋈	1400		1400		7000			
	Aft	140		140		700			
Tanker	Fwd	500		500		2000	7-H-6		
	⋈	10000		10000		24000			
	Aft	800		800		4000			
General Cargo	Fwd	100		100		600	7-H-7		
	⋈	79	1	80	1.2	200		1	8,12
	Aft								
Tanker	Fwd	600		600		1200	7-H-7		
	⋈	50		50		200			
	Aft								
Bulk Carrier	Fwd	40		40		100	7-H-8		
	⋈								
	Aft								
Tanker	Fwd	30		30		100	7-H-8		
	⋈	400		400		800			
	Aft	60		60		200			
Bulk Carrier	Fwd	200		200		1000	7-H-9		
	⋈	1200		1200		7000			
	Aft	400		400		2000			
Combination Carrier	Fwd	200		200		500	7-H-9		
	⋈	700		700		3500			
	Aft	300		300		1000			
Containership	Fwd	1800		1800		8800	7-H-9		
	⋈	10000		10000		51000			
	Aft	3000		3000		15000			
General Cargo	Fwd	500		500		2500	7-H-9		
	⋈	4000		4000		18000			
	Aft	1000		1000		4500			
Miscellaneous	Fwd	300		300		1000	7-H-9		
	⋈	1500		1500		7000			
	Aft	700		700		2000			
Naval	Fwd	1000		1000		3800	7-H-9		
	⋈	7000		7000		22000			
	Aft	2000		2000		6000			
Tanker	Fwd	2000		2000		8000	7-H-9		
	⋈	25000		25000		65000			
	Aft	4000		4000		17000			
Bulk Carrier	Fwd	200		200		600	7-H-10		
	⋈	1000		1000		4200			
	Aft	500		500		1200			
Combination Carrier	Fwd	400		400		1600	7-H-10		
	⋈	3000		3000		11000			
	Aft	800		800		3000			
Containership	Fwd	400		400		2000	7-H-10		
	⋈	2500		2500		12800			
	Aft	900		900		3000			



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-7 DETAIL FAMILY: MISCELLANEOUS CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	200	16	200	1.2	800	7-H-10	1	12
	Mid	1284		1300		6000			
	Aft	400		400		1800			
Miscellaneous	Fwd	100		100		200	7-H-10		
	Mid	300		300		1000			
	Aft	100		100		300			
Naval	Fwd	400		400		2000	7-H-10		
	Mid	2800		2800		14000			
	Aft	800		800		4000			
Tanker	Fwd	200		200		680	7-H-10		
	Mid	2500		2500		5600			
	Aft	500		500		1500			
Tanker	Fwd	9	1	10	10.0	20	7-H-11	1	8,14
	Mid								
	Aft								
Combination Carrier	Fwd						7-H-12		
	Mid								
	Aft	47	3	50	6.0	100		1	13
Containership	Fwd						7-H-12		
	Mid								
	Aft	100		100		200			
Tanker	Fwd						7-H-12		
	Mid								
	Aft	50		50		100			

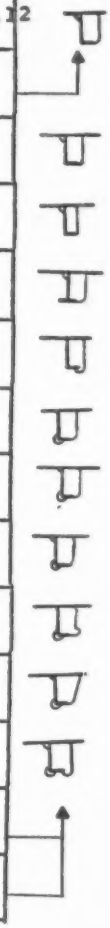
TABLE A-8 DETAIL FAMILY: CLEARANCE CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd		36	270	13.3	300	8-A-1	1	8
	Mid	234							
	Aft								
Containership	Fwd	150		150		400	8-A-2		
	Mid								
	Aft								
Bulk Carrier	Fwd	150		150		500	8-B-1		
	Mid	300		300		1500			
	Aft								
Containership	Fwd						8-B-1		
	Mid								
	Aft	100		100		200			
Combination Carrier	Fwd		1	20		30	8-B-2	1	8,9
	Mid	19							
	Aft								
Containership	Fwd						8-B-2		
	Mid								
	Aft	39	1	40	2.5	50		1	9
General Cargo	Fwd	30		30		200	8-B-2		
	Mid								
	Aft	100		100		300			

BEST DOCUMENT AVAILABLE

TABLE A-8 DETAIL FAMILY: CLEARANCE CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	150		150		400	8-B-2	1,2	8,11,12
	⋈	1958	22	1980	1.0	3870		1	8
	Aft	496	4	500	.8	1300			
General Cargo	Fwd						8-B-3		
	⋈								
	Aft	50		50		100			
Tanker	Fwd						8-B-3		
	⋈	2400		2400		5100			
	Aft	100		100		200			
Bulk Carrier	Fwd						8-B-4		
	⋈								
	Aft	40		40		100			
Naval	Fwd						8-B-5		
	⋈								
	Aft	70		70		200			
Containership	Fwd						8-B-6	1	5,10
	⋈								
	Aft	188	2	190	1.1	400			
Tanker	Fwd	80		80		200	8-C-1		
	⋈								
	Aft								
Tanker	Fwd	300		300		900	8-C-2	1	14
	⋈	628	72	700	10.3	3000			
	Aft	70		70		100			
Containership	Fwd	300		300		900	8-C-3		
	⋈	1100		1100		5500		1	9
	Aft	59	1	60	1.7	100			
Containership	Fwd	100		100		400	8-C-4		
	⋈								
	Aft								
Containership	Fwd	68	2	70	2.9	200	8-C-5	1	14
	⋈								
	Aft	650		650		1400			
Bulk Carrier	Fwd	40		40		100	8-C-6		
	⋈	400		400		1800			
	Aft	40		40		100			
Miscellaneous	Fwd	80		80		200	8-C-6		
	⋈								
	Aft								
Tanker	Fwd						8-C-6		
	⋈								
	Aft	200		200		500			



NOTES:
(A) The above continued table gives information related to individual detail designs in the 50 ship survey.
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(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.
(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

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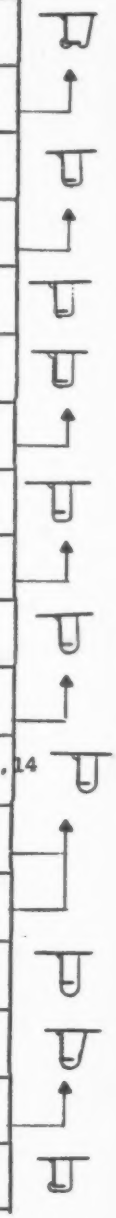
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-8 DETAIL FAMILY: CLEARANCE CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	400		400		1000	8-C-7		
	Aft	3200		3200		16000			
		1100		1100		3000			
Containership	Fwd	150		150		800	8-C-7		
	Aft								
Containership	Fwd	146	4	150	2.7	400	8-D-1	1	9
	Aft	50		50		100			
Tanker	Fwd								
	Aft	150		150		300	8-D-1		
Tanker	Fwd	100		100		300			
		755	45	800	5.6	2000	8-D-2	1	8,9
	Aft	150		150		400			
Bulk Carrier	Fwd								
	Aft	80		80		200	8-D-3		
Containership	Fwd								
	Aft	60		60		100	8-D-3		
General Cargo	Fwd								
	Aft	60		60		100	8-D-4		
Miscellaneous	Fwd	50		50		150			
		240		240		800	8-D-4		
	Aft	100		100		250			
Containership	Fwd	146	4	150	2.7	500	8-D-5	1	5,8
	Aft								
Tanker	Fwd	170		170		600			
		1880	120	2000	6.0	8800	8-D-5	1	5,8
	Aft	400		400		1300			
Combination Carrier	Fwd	500		500		1400			
		3850	350	4200	8.3	16300	8-D-6	1	5,8,11,14
	Aft	900		900		2000			
Miscellaneous	Fwd	60		60		200	8-D-6		
		2100		2100		6800			
	Aft	300		300		1000			
Tanker	Fwd	60		60		200			
		530	70	600	11.7	1100	8-D-6	1	8,14
	Aft	100		100		300			
Tanker	Fwd	30		30		100			
		90		90		300	8-D-7		
	Aft	60		60		200			
Miscellaneous	Fwd								
	Aft	70		70		200	8-D-8		
Tanker	Fwd	300		300		800	8-D-8		
	Aft								
General Cargo	Fwd	90		90		300			
		400		400		1600	8-E-1		
	Aft	30		30		100			



BEST DOCUMENT AVAILABLE

TABLE A-8 DETAIL FAMILY: CLEARANCE CUTOUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	126	14	140	10.0	350	8-E-2	1	8,14
	⋈	900		900		5000			
	Aft	200		200		600			
Containership	Fwd	210		210		660	8-E-2	1	5,10
	⋈	949	1	950	.1	5700			
	Aft	400		400		1240			
General Cargo	Fwd	148	2	150		500	8-E-2	1	14
	⋈	870		870		4000			
	Aft	300		300		900			
Tanker	Fwd	110		110		300	8-E-2	1	8,14
	⋈	409	11	420	2.6	1400			
	Aft	90		90		300			
Containership	Fwd	100		100		350	8-E-3		
	⋈								
	Aft								
Tanker	Fwd	60		60		100	8-E-3		
	⋈								
	Aft								
Bulk Carrier	Fwd								
	⋈	120		120		400	8-E-4		
	Aft								
Tanker	Fwd	146	4	150		500	8-E-5	1,2	15
	⋈	2376	24	2400	1.0	5800		1,2	5,14
	Aft	100		100		300			
Bulk Carrier	Fwd								
	⋈								
	Aft	98	2	100	2.0	150	8-E-6	2	15
Tanker	Fwd	229	1	230	.4	700	8-E-6	1	15
	⋈	2484	16	2500	.6	6000		2	14,15
	Aft	160		160		400			
Combination Carrier	Fwd	108	12	120	10.0	300	8-E-7	1,2	8,14
	⋈	110		110		300			
	Aft								
Containership	Fwd	120		120		400	8-E-8		
	⋈	1500		1500		9000			
	Aft	200		200		600			
Containership	Fwd	140		140		400	8-E-9		
	⋈	2200		2200		9000			
	Aft	260		260		600			
Tanker	Fwd								
	⋈	920		920		2100	8-E-10		
	Aft								
Tanker	Fwd								
	⋈	800		800		1500	8-E-11		
	Aft								
Tanker	Fwd								
	⋈	1200		1200		2200	8-E-12		
	Aft								

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-9 DETAIL FAMILY: STRUCTURAL DECK CUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd Aft	20		20		30	9-A-1		
Combination Carrier	Fwd Aft	10		10		10	9-A-1		
Containership	Fwd Aft	10 10		10 10		10 20	9-A-1		
General Cargo	Fwd Aft	10		10		10	9-A-1		
Tanker	Fwd Aft	900 30		900 30		1230 50	9-A-1		
Combination Carrier	Fwd Aft	20 10 10		20 10 10		40 30 10	9-A-2		
Containership	Fwd Aft	10 10		10 10		10 10	9-A-2		
General Cargo	Fwd Aft	10		10		10	9-A-2		
Miscellaneous	Fwd Aft	10 20 10		10 20 10		10 30 10	9-A-2		
Tanker	Fwd Aft	20 40		20 40		30 50	9-A-2		
Bulk Carrier	Fwd Aft	20 20 20		20 20 20		30 40 30	9-A-3		
Combination Carrier	Fwd Aft	20 40 20		20 40 20		20 100 20	9-A-3		
Containership	Fwd Aft	20 30 30		20 30 30		30 60 50	9-A-3		
Tanker	Fwd Aft	20 59	1	20 60	1.7	20 90	9-A-3	1	8
Combination Carrier	Fwd Aft	10		10		10	9-A-4		
Naval	Fwd Aft	10		10		10	9-A-4		
Tanker	Fwd Aft	10		10		10	9-A-4		
Combination Carrier	Fwd Aft	20 90 30		20 90 30		30 140 40	9-A-5		
Containership	Fwd Aft	30 50 30		30 50 30		40 110 50	9-A-5		

BEST DOCUMENT AVAILABLE

TABLE A-9 DETAIL FAMILY: STRUCTURAL DECK CUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	20		20		20	9-A-5		
	⋈	30		30		60			
	Aft	30		30		40			
Miscellaneous	Fwd	80		80		120	9-A-5		
	⋈	60		60		100			
	Aft	150		150		220			
Combination Carrier	Fwd	10		10		10	9-A-6		
	⋈								
	Aft								
Miscellaneous	Fwd	10		10		10	9-A-6		
	⋈								
	Aft								
Tanker	Fwd	10		10		10	9-A-6		
	⋈								
	Aft								
Bulk Carrier	Fwd	30		30		40	9-A-7		
	⋈	30		30		60			
	Aft								
Containership	Fwd						9-A-7		
	⋈								
	Aft	10		10		10			
Tanker	Fwd						9-A-7		
	⋈								
	Aft	10		10		10			
Tanker	Fwd						9-A-8		
	⋈	250		250		340			
	Aft								
General Cargo	Fwd	20		20		30	9-A-9		
	⋈	40		40		120			
	Aft	40		40		50			
Tanker	Fwd						9-A-9		
	⋈	60		60		60			
	Aft								
Bulk Carrier	Fwd	10		10		10	9-B-1		
	⋈	50		50		80			
	Aft	10		10		20			
Containership	Fwd						9-B-1		
	⋈	26	4	30	13.3	40		1	10
	Aft								
Miscellaneous	Fwd						9-B-1		
	⋈	10		10		20			
	Aft								
Naval	Fwd	30		30		50	9-B-1		
	⋈	120		120		200			
	Aft	40		40		60			

NOTES:

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6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-9 DETAIL FAMILY: STRUCTURAL DECK CUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	10		10		20	9-B-1		
	Aft	10		10		10			
Combination Carrier	Fwd	10		10		10	9-B-2		
	Aft								
Containership	Fwd	40		40		60	9-B-2		
	Aft	10		10		20			
	Aft	10		10		20			
General Cargo	Fwd	20		20		40	9-B-2		
	Aft								
Naval	Fwd	20		20		30	9-B-2		
	Aft	120		120		160			
	Aft	10		10		10			
Tanker	Fwd	10		10		10	9-B-2		
	Aft	10		10		10			
	Aft	10		10		20			
Combination Carrier	Fwd	10		10		10	9-B-3	1	8
	Aft	69	1	70	1.4	140			
	Aft	10		10		10			
Containership	Fwd	40		40		70	9-B-3		
	Aft	110		110		260			
	Aft	20		20		30			
Miscellaneous	Fwd						9-B-3		
	Aft	20		20		30			
	Aft	10		10		10			
Naval	Fwd	40		40		60	9-B-3		
	Aft	260		260		360			
	Aft	80		80		110			
Tanker	Fwd	20		20		30	9-B-3		
	Aft	40		40		50			
Bulk Carrier	Fwd	20		20		40	9-B-4		
	Aft								
Miscellaneous	Fwd	10		10		10	9-B-4		
	Aft	10		10		20			
Naval	Fwd	10		10		20	9-B-4		
	Aft	20		20		20			
Tanker	Fwd						9-B-4		
	Aft	10		10		10			
Bulk Carrier	Fwd	20		20		30	9-B-5		
	Aft	10		10		10			
Combination Carrier	Fwd	10		10		20	9-B-5		
	Aft	20		20		30			
	Aft	20		20		40			
Containership	Fwd	80		80		100	9-B-5		
	Aft	70		70		290			
	Aft	90		90		160			
General Cargo	Fwd	10		10		20	9-B-5		
	Aft	30		30		40			
	Aft	10		10		20			

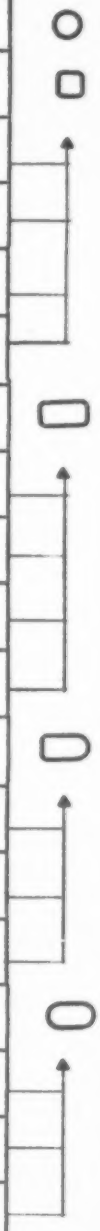

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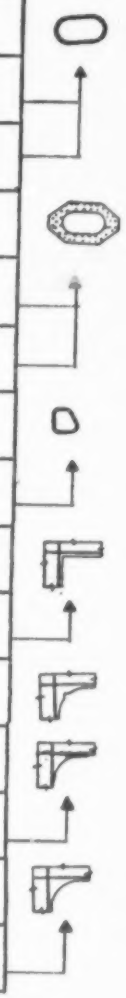
TABLE A-9 DETAIL FAMILY: STRUCTURAL DECK CUTS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Miscellaneous	Fwd	10		10		10	9-B-5		
	▯	10		10		20			
	Aft	10		10		10			
Naval	Fwd	60		60		90	9-B-5		
	▯	300		300		420			
	Aft	110		110		140			
Tanker	Fwd	50		50		60	9-B-5		
	▯	50		50		60			
	Aft	60		60		70			
Combination Carrier	Fwd ▯ Aft	10		10		10	9-B-6		
Containership	Fwd ▯ Aft	10		10		20	9-B-6		
Tanker	Fwd ▯ Aft	20		20		20	9-B-6		
Naval	Fwd ▯ Aft	10		10		10	9-B-7		
Tanker	Fwd ▯ Aft	10		10		10	9-B-7		
Bulk Carrier	Fwd ▯ Aft	30		30		50	9-C-1		
Combination Carrier	Fwd ▯ Aft	30		30		30	9-C-1		
Combination Carrier	Fwd ▯ Aft	4	6	10	60.0	10	9-C-2	1	8
Combination Carrier	Fwd ▯ Aft	20		20		20	9-C-3		
Containership	Fwd ▯ Aft	40		40		100	9-C-3		
Bulk Carrier	Fwd ▯ Aft	40		40		80	9-C-4		
Combination Carrier	Fwd ▯ Aft	100		100		120	9-C-4		



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ▯ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

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6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-9 DETAIL FAMILY: STRUCTURAL DECK CUTS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd ▯ Aft	260		260		850	9-C-4		
General Cargo	Fwd ▯ Aft	180		180		320	9-C-4		
Containership	Fwd ▯ Aft	10		10		20	9-C-5		
Bulk Carrier	Fwd ▯ Aft	30		30		40	9-C-6		
Containership	Fwd ▯ Aft	30		30		70	9-C-6		
General Cargo	Fwd ▯ Aft	90		90		160	9-C-6		
Naval	Fwd ▯ Aft	40		40		50	9-C-7		

TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Combination Carrier	Fwd ▯ Aft	10		10		10	10-A-1		
Containership	Fwd ▯ Aft	8 14	2 6	10 20	20.0 30.0	10 20	10-A-1	1 1	8, 10 8, 10
Containership	Fwd ▯ Aft	99 20 20	1	100 20 20	1.0	120 30 30	10-A-2	1	6,10
General Cargo	Fwd ▯ Aft	20 20		20 20		20 20	10-A-2		
Miscellaneous	Fwd ▯ Aft	50 130 60		50 130 60		50 210 60	10-A-2		
Tanker	Fwd ▯ Aft	20 10 20		20 10 20		20 10 30	10-A-2		
Miscellaneous	Fwd ▯ Aft	10		10		10	10-A-3		
Naval	Fwd ▯ Aft	50 150 30		50 150 30		50 200 50	10-A-3		

BEST DOCUMENT AVAILABLE

TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	20		20		20	10-A-4		
	⋈	70		70		90			
	Aft	20		20		30			
Containership	Fwd	20		20		20	10-A-5		
	⋈								
	Aft								
Tanker	Fwd	20		20		30	10-A-5		
	⋈								
	Aft	20		20		20			
Bulk Carrier	Fwd						10-A-6		
	⋈								
	Aft	20		20		20			
Bulk Carrier	Fwd						10-A-7		
	⋈								
	Aft	10		10		10			
Combination Carrier	Fwd	20		20		30	10-A-7		
	⋈								
	Aft	20		20		20			
Tanker	Fwd						10-A-8		
	⋈								
	Aft	20		20		20			
Bulk Carrier	Fwd						10-A-9		
	⋈								
	Aft	10		10		10			
Naval	Fwd	20		20		20	10-A-9		
	⋈								
	Aft	20		20		20			
Combination Carrier	Fwd						10-A-10		
	⋈								
	Aft	10		10		10			
General Cargo	Fwd						10-A-10		
	⋈								
	Aft	10		10		10			
Naval	Fwd	10		10		10	10-A-10		
	⋈								
	Aft	20		20		30			
Combination Carrier	Fwd	20		20		20	10-A-11		
	⋈								
	Aft	10		10		10			
Combination Carrier	Fwd	40		40		50	10-A-12		
	⋈								
	Aft	40		40		40			
Containership	Fwd	10		10		10	10-A-12		
	⋈								
	Aft								

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

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5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

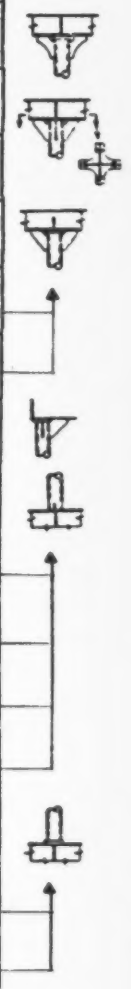
TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	10		10		10			
		14	36	50	72.0	50	10-A-12	1,4	12
	Aft	10		10		10			
Miscellaneous	Fwd	30		30		40			
	Aft	10		10		10	10-A-12		
Tanker	Fwd	130		130		180			
	Aft	20		20		20	10-A-12		
Containership	Fwd								
	Aft	10		10		10	10-A-13		
Miscellaneous	Fwd	10		10		10			
	Aft						10-A-14		
Tanker	Fwd								
	Aft	10		10		10	10-A-14		
Containership	Fwd								
	Aft	10		10		10	10-A-15		
Tanker	Fwd	30		30		50			
	Aft						10-A-15		
Combination Carrier	Fwd	20		20		30			
	Aft						10-A-16		
Naval	Fwd								
	Aft	10		10		10	10-A-16		
Combination Carrier	Fwd								
	Aft	10		10		10	10-A-17		
Tanker	Fwd								
	Aft	20		20		20	10-A-17		
Miscellaneous	Fwd								
	Aft	10		10		10	10-A-18		
General Cargo	Fwd								
	Aft	10		10		10	10-A-19		
Tanker	Fwd								
	Aft	20		20		20	10-A-19		
Combination Carrier	Fwd								
	Aft	10		10		20	10-A-20		
Naval	Fwd	10		10		10			
		20		20		20	10-A-21		
	Aft	10		10		20			
Bulk Carrier	Fwd	40		40		50			
	Aft	40		40		50	10-A-22		
Miscellaneous	Fwd	20		20		20			
	Aft						10-A-22		

BEST DOCUMENT AVAILABLE

TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	10		10		10	10-A-22		
	▯								
	Aft	40		40		60			
Bulk Carrier	Fwd	20		20		20	10-A-23		
	▯								
	Aft	20		20		20			
Containership	Fwd	40		40		50	10-A-23		
	▯								
	Aft								
Bulk Carrier	Fwd	20		20		20	10-A-24		
	▯								
	Aft								
General Cargo	Fwd	40		40		50	10-A-24		
	▯								
	Aft								
Tanker	Fwd	20		20		20	10-A-24		
	▯								
	Aft	10		10		10			
Containership	Fwd								
	▯	10		10		10	10-A-25		
	Aft								
Combination Carrier	Fwd	20		20		30	10-B-1		
	▯								
	Aft	20		20		20			
Containership	Fwd								
	▯								
	Aft	20		20		20	10-B-1		
General Cargo	Fwd	20		20		30			
	▯	10		10		10	10-B-1		
	Aft	10		10		10			
Naval	Fwd	10		10		10			
	▯	20		20		20	10-B-1		
	Aft	20		20		20			
Tanker	Fwd	20		20		20	10-B-1		
	▯								
	Aft								
Bulk Carrier	Fwd	70		70		80	10-B-2		
	▯								
	Aft	70		70		80			
Combination Carrier	Fwd	60		60		60			
	▯					10	10-B-2		
	Aft	60		60		70			
Containership	Fwd	120		120		150			
	▯	20		20		50	10-B-2		
	Aft	50		50		60			



NOTES:

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7. Combined Tension and Shear
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9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

BEST DOCUMENT AVAILABLE

TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd	20		20		20			
	Mid	20		20		50	10-B-2		
	Aft	30		30		40			
Miscellaneous	Fwd	40		40		50			
	Mid	10		10		10	10-B-2		
	Aft								
Naval	Fwd	60		60		80			
	Mid	210		210		260	10-B-2		
	Aft	90		90		110			
Tanker	Fwd	208	2	210	1.0	250		1	6,9,13
	Mid	10		10		10	10-B-2		
	Aft	130		130		150			
Miscellaneous	Fwd								
	Mid						10-B-3		
	Aft	10		10		10			
Combination Carrier	Fwd								
	Mid						10-B-4		
	Aft	10		10		10			
Bulk Carrier	Fwd								
	Mid						10-B-5		
	Aft	10		10		10			
Naval	Fwd								
	Mid						10-B-6		
	Aft	20		20		20			
Naval	Fwd								
	Mid						10-B-7		
	Aft	20		20		20			
		20		20		20			
Containership	Fwd								
	Mid						10-B-8		
	Aft	10		10		10			
Naval	Fwd	50		50		60			
	Mid	190		190		210	10-B-8		
	Aft	40		40		50			
Tanker	Fwd								
	Mid						10-B-8		
	Aft	10		10		10			
		10		10		10			
Combination Carrier	Fwd								
	Mid						10-B-9		
	Aft		20	20	100.0	20		1	8
Containership	Fwd								
	Mid						10-B-9		
	Aft		10	10	100.0	10		1	8
General Cargo	Fwd								
	Mid						10-B-10		
	Aft	40		40		50			
Naval	Fwd								
	Mid						10-B-10		
	Aft	20		20		20			
		10		10		10			
Naval	Fwd								
	Mid						10-B-11		
	Aft	20		20		20			
		20		20		30			
Combination Carrier	Fwd								
	Mid						10-B-12		
	Aft	20		20		20			

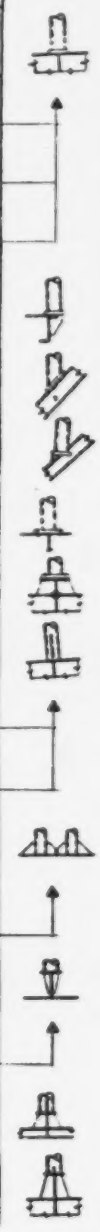

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TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd								
	Aft	10		10		10	10-B-12		
Tanker	Fwd	20		20		30	10-B-12		
	Aft								
Containership	Fwd	40		40		50	10-B-13		
	Aft								
Naval	Fwd	10		10		10	10-B-13		
	Aft	10		10		10			
Bulk Carrier	Fwd	20		20		20	10-B-14		
	Aft								
Naval	Fwd	40		40		40			
		60		60		80	10-B-15		
	Aft	50		50		60			
Tanker	Fwd	30		30		30			
	Aft	20		20		20	10-B-15		
Bulk Carrier	Fwd								
	Aft	30		30		40	10-B-15		
Combination Carrier	Fwd	10		10		30	10-B-15		
	Aft	10		10		10			
Containership	Fwd	10		10		10	10-B-15		
	Aft	30		30		30			
General Cargo	Fwd	40		40		100	10-B-15		
	Aft	10		10		10			
Bulk Carrier	Fwd	10		10		10			
	Aft	10		10		20	10-B-16		
Combination Carrier	Fwd	30		30		30			
		30		30		60	10-B-16		
	Aft	10		10		10			
Containership	Fwd	30		30		30			
		20		20		40	10-B-16		
	Aft	20		20		30			
General Cargo	Fwd	50		50		110	10-B-16		
	Aft	10		10		20			

NOTES:

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(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Miscellaneous	Fwd Aft	10		10		10	10-B-16		
Naval	Fwd Aft	30 80 50		30 80 50		40 110 90	10-B-16		
Tanker	Fwd Aft	10 70		10 70		10 110	10-B-16		
General Cargo	Fwd Aft	40		40		50	10-B-17		
Combination Carrier	Fwd Aft	20		20		20	10-B-18		
General Cargo	Fwd Aft	30		30		50	10-B-18		
Naval	Fwd Aft	20		20		30	10-B-19		
Combination Carrier	Fwd Aft	10		10		10	10-B-20		
Containership	Fwd Aft	28	2	30	6.7	30	10-B-21	1	8,10
Tanker	Fwd Aft	10		10		10	10-B-21		
Containership	Fwd Aft	8	2	10	20.0	10	10-B-22	1	8
Tanker	Fwd Aft	20		20		20	10-B-23		
Bulk Carrier	Fwd Aft	4	6	10	60.0	10	10-B-24	3	8
Tanker	Fwd Aft	9	1	10	10.0	10	10-B-25	1	12
Containership	Fwd Aft	8	2	10	20.0	10	10-C-1	1	8
Containership	Fwd Aft	20		20		20	10-C-2		
Tanker	Fwd Aft	30		30		30	10-C-2		
Naval	Fwd Aft	20		20		30	10-C-3		
Tanker	Fwd Aft	10		10		10	10-C-3		

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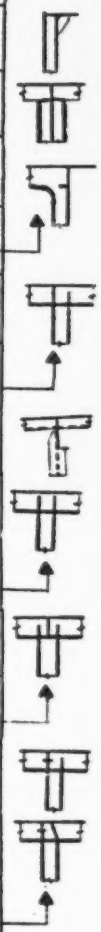
TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd Aft	10		10		10	10-C-4		
Bulk Carrier	Fwd Aft	4	6	10	60.0	10	10-C-5	1	8
Combination Carrier	Fwd Aft	10		10		10	10-C-6		
General Cargo	Fwd Aft	8	2	10	20.0	10	10-C-6	1,2	12
Containership	Fwd Aft	10		10		10	10-C-7		
Tanker	Fwd Aft	20		20		40	10-C-7		
Tanker	Fwd Aft	20		20		20	10-C-8		
Combination Carrier	Fwd Aft	10		10		10	10-C-9		
General Cargo	Fwd Aft	20 20		20 20		50 20	10-C-9		
Bulk Carrier	Fwd Aft	20		20		20	10-C-10		
Combination Carrier	Fwd Aft	10		10		30	10-C-10		
Tanker	Fwd Aft	20		20		30	10-C-11		
General Cargo	Fwd Aft	20		20		50	10-C-12		
Naval	Fwd Aft	20 20		20 20		20 20	10-C-12		



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6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
General Cargo	Fwd Aft	40		40		50	10-C-13		
Naval	Fwd Aft	30 70 20		30 70 20		40 80 20	10-C-13		
Naval	Fwd Aft	50 30 20		50 30 20		60 40 20	10-C-14		
General Cargo	Fwd Aft	40		40		50	10-C-15		
Containership	Fwd Aft	10		10		10	10-C-16		
General Cargo	Fwd Aft	20		20		50	10-C-16		
Bulk Carrier	Fwd Aft	10		10		10	10-C-17		
Combination Carrier	Fwd Aft	20		20		30	10-C-18		
Naval	Fwd Aft	20		20		30	10-C-18		
Combination Carrier	Fwd Aft	10		10		30	10-C-19		
Naval	Fwd Aft	20 40 20		20 40 20		20 60 20	10-C-20		
Bulk Carrier	Fwd Aft	20		20		20	10-C-21		
Containership	Fwd Aft	10 10		10 10		10 40	10-C-21		
General Cargo	Fwd Aft	20 10		20 10		50 10	10-C-21		
Tanker	Fwd Aft	30		30		40	10-C-21		
Containership	Fwd Aft	10		10		20	10-C-22		
Tanker	Fwd Aft	10		10		10	10-C-22		
General Cargo	Fwd Aft	10		10		20	10-C-23		

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TABLE A-10 DETAIL FAMILY: STANCHION ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd Aft	20		20		20	10-C-24		
Containership	Fwd Aft	10		10		10	10-C-25		
Miscellaneous	Fwd Aft	10		10		10	10-C-25		
Naval	Fwd Aft	10 10 10		10 10 10		10 20 10	10-C-25		
Containership	Fwd Aft	20		20		20	10-C-26		
Tanker	Fwd Aft	10		10		10	10-C-26		
Containership	Fwd Aft	20		20		20	10-C-27		
Combination Carrier	Fwd Aft	10		10		10	10-C-28		
Bulk Carrier	Fwd Aft	20		20		30	10-C-29		

TABLE A-11 DETAIL FAMILY: STIFFENER ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd Aft	200 190	10	200 200	5.0	450 450	11-A-1	1	5
Combination Carrier	Fwd Aft	280 300 300		280 300 300		750 900 700	11-A-1		

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

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(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-11 DETAIL FAMILY: STIFFENER ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	90		90		180			
	∫	290		290		900	11-A-1		
	Aft	340		340		700			
General Cargo	Fwd	70		70		130			
	∫	173	7	180	3.9	510	11-A-1	1	5
	Aft	118	2	120	1.7	280		1	5
Miscellaneous	Fwd	50		50		100			
	∫	60		60		150	11-A-1		
	Aft	80		80		180			
Tanker	Fwd	700		700		1350			
	∫	1523	77	1600	4.8	4800	11-A-1	1	5
	Aft	650		650		1200			
Containership	Fwd	80		80		150			
	∫	118	2	120	1.7	400	11-A-2	1	5
	Aft	80		80		150			
General Cargo	Fwd								
	∫								
	Aft	10		10		20	11-A-2		
Tanker	Fwd	20		20		30			
	∫						11-A-2		
	Aft								
Bulk Carrier	Fwd	20		20		40			
	∫						11-A-3		
	Aft								
Containership	Fwd	290		290		610			
	∫	207	3	210	1.4	700	11-A-3	1	5
	Aft	110		110		280			
General Cargo	Fwd								
	∫	30		30		100			
	Aft	50		50		100	11-A-3		
Naval	Fwd	19	1	20	5.0	50		1	6,8,14
	∫						11-A-3		
	Aft	20		20		40			
Tanker	Fwd	30		30		60			
	∫						11-A-3		
	Aft	60		60		140			
Naval	Fwd	50		50		130			
	∫	120		120		300	11-A-4		
	Aft	70		70		170			
Containership	Fwd	19	1	20	5.0	20	11-A-5	1	5
	∫								
	Aft								
Tanker	Fwd	20		20		30	11-A-5		
	∫								
	Aft								
Containership	Fwd								
	∫	97	3	100	3.0	300		1	5,7
	Aft	18	2	20	10.0	20	11-A-6	2	8
Naval	Fwd								
	∫	63	7	70	10.0	100	11-A-6	1	7
	Aft								
Bulk Carrier	Fwd	170		170		350			
	∫	430		430		1400	11-A-7		
	Aft	210		210		450			
Combination Carrier	Fwd	375	5	380	1.3	820		1	14
	∫	360		360		1200	11-A-7		
	Aft	250		250		450			

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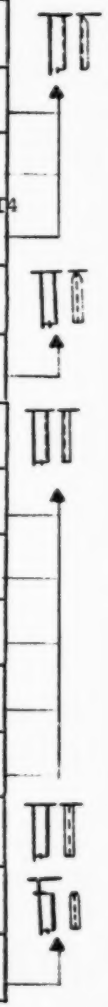
TABLE A-11 DETAIL FAMILY: STIFFENER ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	547	3	550	.5	1240	11-A-7	1	14,15
	⋈	1104	6	1110	.5	3500		1	8
	Aft	660		660		1480			
General Cargo	Fwd	210		210		490	11-A-7		
	⋈	1120		1120		3800			
	Aft	500		500		1110			
Miscellaneous	Fwd	110		110		190	11-A-7		
	⋈	30		30		100			
	Aft	100		100		190			
Tanker	Fwd	604	6	610	1.0	1280	11-A-7	1	7,11,14
	⋈	820		820		1620			
	Aft	540		540		1580			
Combination Carrier	Fwd	200		200		600	11-A-8		
	⋈								
	Aft								
Naval	Fwd	80		80		170	11-A-8		
	⋈	420		420		1020			
	Aft	166	4	170	2.4	380		1	8,14
Bulk Carrier	Fwd	80		80		200	11-A-9		
	⋈								
	Aft	170		170		400			
Combination Carrier	Fwd	40		40		100	11-A-9		
	⋈								
	Aft	90		90		200			
Containership	Fwd	50		50		100	11-A-9		
	⋈	120		120		400			
	Aft	150		150		310			
General Cargo	Fwd	60		60		160	11-A-9		
	⋈	120		120		400			
	Aft	110		110		240			
Naval	Fwd	240		240		600	11-A-9		
	⋈	1600		1600		4200			
	Aft	300		300		1200			
Tanker	Fwd	87	3	90	3.3	200	11-A-9	1	11
	⋈								
	Aft	130		130		250			
Naval	Fwd	230		230		580	11-A-10		
	⋈	1500		1500		3500			
	Aft	400		400		1020			
Containership	Fwd						11-A-11		
	⋈								
	Aft	20		20		20			
Naval	Fwd	60		60		100	11-A-11		
	⋈								
	Aft								



NOTES:

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8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-11 DETAIL FAMILY: STIFFENER ENDS

SHIP TYPE / LOCATION ON SHIP		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Tanker	Fwd	50		50		100	11-A-11		
	Aft	60		60		100			
Bulk Carrier	Fwd								
	Aft	20		20		20	11-A-12		
Naval	Fwd	30		30		60			
		110		110		240	11-A-12		
	Aft	50		50		100			
Tanker	Fwd								
	Aft	40		40		60	11-A-12		
Combination Carrier	Fwd	30		30		50	11-B-1		
	Aft	30		30		50			
Containership	Fwd								
		58	2	60	3.3	200	11-B-1	1	5
	Aft	80		80		180			
Tanker	Fwd	20		20		20			
		195	5	200	2.5	400	11-B-1	1	7
	Aft	16	4	20		20		1	5
Containership	Fwd								
		60		60		200	11-B-2		
	Aft								
Containership	Fwd	50		50		100			
		352	8	360	2.2	1200	11-B-3	1	7
	Aft	247	3	250	1.2	500		2	14
General Cargo	Fwd								
		60		60		200	11-B-3		
	Aft								
General Cargo	Fwd	20		20		50			
		90		90		350	11-B-4		
	Aft	50		50		100			
Tanker	Fwd								
		1908	12	1920	.6	3200	11-B-4	1	7
	Aft								
Containership	Fwd								
	Aft	59	1	60	1.7	100	11-B-5	1	7
Containership	Fwd								
		9	1	10	10.0	20	11-B-6	1	8
	Aft								
General Cargo	Fwd								
	Aft	30		30		60	11-C-1		
Tanker	Fwd	50		50		100	11-C-1		
	Aft								
Tanker	Fwd								
	Aft	40		40		100	11-C-2		
Naval	Fwd	40		40		80			
		170		170		410	11-C-3		
	Aft	60		60		150			
Naval	Fwd	40		40		50			
		60		60		100	11-C-4		
	Aft	40		40		50			

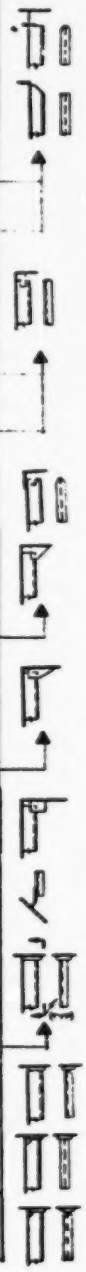

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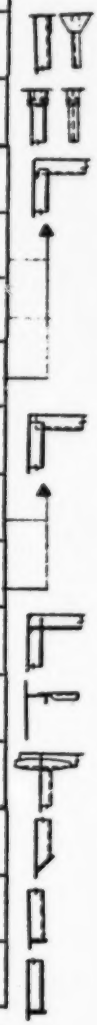
TABLE A-11 DETAIL FAMILY: STIFFENER ENDS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd Aft	60		60		110	11-C-5		
Naval	Fwd Aft	13	7	20	35.0	20	11-C-6	1	8
Combination Carrier	Fwd Aft	20 20		20 20		50 50	11-D-1		
Containership	Fwd Aft	60		60		120	11-D-1		
General Cargo	Fwd Aft	30		30		50	11-D-1		
Tanker	Fwd Aft	110		110		200	11-D-1		
Containership	Fwd Aft	60		60		200	11-D-2		
Miscellaneous	Fwd Aft	50 40		50 40		110 90	11-D-2		
Tanker	Fwd Aft	30 60		30 60		50 100	11-D-2		
Naval	Fwd Aft	200 1060 360		200 1060 360		560 2700 1250	11-D-3		
Containership	Fwd Aft	58	2	60	1.7	200	11-D-4	1	7
Tanker	Fwd Aft	2108 160	42	2150 160	2.0	4200 400	11-D-5	1	7
General Cargo	Fwd Aft	60		60		200	11-E-1		
Tanker	Fwd Aft	10 120		10 120		10 300	11-E-2		
Tanker	Fwd Aft	20 20		20 20		30 40	11-E-3		



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7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd Aft	6	24	30	80.0	30	12-A-1	1	5, 8
Tanker	Fwd Aft	150 60 330		150 60 330		300 100 600	12-A-1		
General Cargo	Fwd Aft	20		20		30	12-A-2		
Tanker	Fwd Aft	40		40		50	12-A-2		
Bulk Carrier	Fwd Aft	30 156 60	4	30 160 60	2.5	40 490 110	12-A-3	1	15
Combination Carrier	Fwd Aft	120 400 210		120 400 210		240 1220 440	12-A-3		
Containership	Fwd Aft	150 600 320		150 600 320		320 2050 630	12-A-3		
General Cargo	Fwd Aft	100 296 215	4 5	100 300 220	1.3 2.3	210 1000 390	12-A-3	1 1	8 11
Miscellaneous	Fwd Aft	40 60 70		40 60 70		70 180 150	12-A-3		
Naval	Fwd Aft	200 2100 400		200 2100 400		500 5500 1000	12-A-3		
Tanker	Fwd Aft	210 670 490		210 670 490		460 1310 1070	12-A-3		
Naval	Fwd Aft	150		150		220	12-A-4		
Tanker	Fwd Aft	90		90		160	12-A-4		
Combination Carrier	Fwd Aft	60		60		100	12-A-5		
General Cargo	Fwd Aft	10		10		30	12-A-5		
Miscellaneous	Fwd Aft	40		40		50	12-A-5		
Tanker	Fwd Aft	40		40		50	12-A-5		

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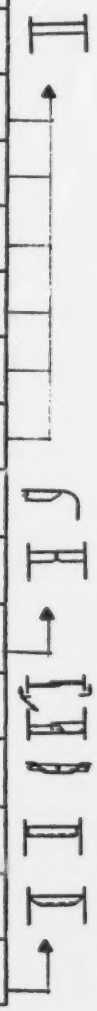
TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	291	9	300		600	12-A-6	1	14
	⋈	1187	13	1200		4240		1	15
	Aft	460		460		990			
Combination Carrier	Fwd	40		40		70	12-A-6		
	⋈	160		160		550			
	Aft	90		90		180			
Containership	Fwd	40		40		60	12-A-6		
	⋈	130		130		440			
	Aft	60		60		100			
General Cargo	Fwd						12-A-6	1	8,13
	⋈	135	5	140		400			
	Aft	70		70		100			
Miscellaneous	Fwd	20		20		30	12-A-6		
	⋈	20		20		60			
	Aft	30		30		40			
Naval	Fwd	50		50		90	12-A-6		
	⋈	400		400		1020			
	Aft	80		80		190			
Tanker	Fwd	80		80		160	12-A-6		
	⋈	260		260		500			
	Aft	230		230		390			
Naval	Fwd						12-A-7	1	5,8
	⋈		10	10	100.0	10			
	Aft								
Bulk Carrier	Fwd						12-A-8	1	8
	⋈								
	Aft	17	3	20	15.0	20			
Naval	Fwd	50		50		120	12-A-8		
	⋈	330		330		840			
	Aft	110		110		240			
Bulk Carrier	Fwd						12-A-9		
	⋈	30		30		100			
	Aft	50		50		100			
Combination Carrier	Fwd						12-A-10	1	5,10
	⋈	702	8	710		2200			
	Aft								
Containership	Fwd	50		50		100	12-B-1		
	⋈	200		200		700			
	Aft	220		220		400			
Containership	Fwd	20		20		20	12-B-2		
	⋈								
	Aft	40		40		60			
General Cargo	Fwd	50		50		80	12-B-2	1	5
	⋈	85	5	90	5.6	300			
	Aft	60		60		100			



NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ⋈ , and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Naval	Fwd	60		60		140	12-B-2		
	Aft								
Tanker	Fwd	30		30		50	12-B-2		
	Aft	50		50		100			
Bulk Carrier	Fwd	30		30		60	12-B-3		
		40		40		170			
	Aft	20		20		30			
Combination Carrier	Fwd	90		90		240	12-B-3		
		270		270		980			
	Aft	190		190		430			
Containership	Fwd	60		60		130	12-B-3		
		120		120		480			
	Aft	116	4	120	3.3	320		1	11,12
General Cargo	Fwd	50		50		100	12-B-3		
		100		100		400			
	Aft	80		80		170			
Miscellaneous	Fwd	20		20		30	12-B-3		
		30		30		120			
	Aft	30		30		50			
Naval	Fwd	20		20		30	12-B-3		
		70		70		230			
	Aft	20		20		40			
Tanker	Fwd	110		110		340	12-B-3		
		210		210		450			
	Aft	200		200		660			
Bulk Carrier	Fwd	10		10		20	12-B-4		
		20		20		90			
	Aft	20		20		40			
Combination Carrier	Fwd	30		30		70	12-B-4		
		70		70		260			
	Aft	60		60		120			
Containership	Fwd	20		20		30	12-B-4		
		30		30		100			
	Aft	30		30		50			
General Cargo	Fwd	10		10		20	12-B-4		
		40		40		120			
	Aft	40		40		60			
Tanker	Fwd	17	3	20	15.0	30	12-B-4	1	14
	Aft								
Naval	Fwd	20		20		50	12-B-5		
		210		210		540			
	Aft	40		40		110			
Naval	Fwd	10		10		20	12-B-6		
		20		20		60			
	Aft	20		20		40			
Naval	Fwd	10		10		20	12-B-7	1	15
		1694	6	1700	.4	4000			
	Aft								
Naval	Fwd	330		330		1160	12-B-8		
		3400		3400		8020			
	Aft	700		700		2570			

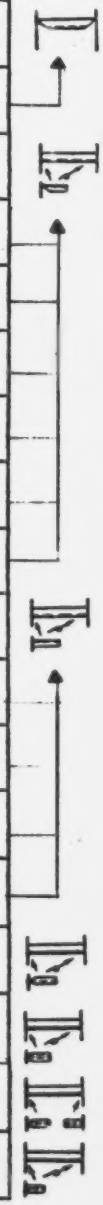

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TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	120		120		400	12-C-1		
	Aft								
General Cargo	Fwd	60	10	70	14.3	200	12-C-1	1	8
	Aft								
Tanker	Fwd	10		10		20	12-C-1		
	Aft	30		30		50			
Naval	Fwd	20		20		40	12-C-2		
		50		50		160			
	Aft	180		180		400			
Bulk Carrier	Fwd	90		90		200	12-C-3		
		60		60		200			
	Aft	190		190		400			
Miscellaneous	Fwd	50		50		120	12-C-3		
		310		310		950			
	Aft	60		60		130			
Tanker	Fwd	350		350		800	12-C-3	1	7,10
		4882	18	4900	4	13000			
	Aft	370		370		700			
Miscellaneous	Fwd	30		30		50	12-C-4		
		230		230		770			
	Aft	50		50		80			
Combination Carrier	Fwd	50		50		100	12-C-4		
		120		120		400			
	Aft	50		50		100			
Containership	Fwd	50		50		100	12-C-4		
		300		300		900			
	Aft	90		90		200			
Tanker	Fwd	240		240		500	12-C-4		
		2200		2200		5500			
	Aft	120		120		200			
General Cargo	Fwd								
	Aft	68	12	80	15.0	150	12-C-5	1	14
Naval	Fwd	50		50		100	12-C-5		
		1000		1000		2700			
	Aft	110		110		200			
Tanker	Fwd	90		90		200	12-C-5		
		740		740		1500			
	Aft	180		180		400			

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

(B) The rows labeled aft, ▯, and fwd refer to locations along the ship length. The midship symbol row covers the mid-length throughout the entire cargo section.

(C) The numbers 1, 2, 3 & 4 in the column for failure mode refer to cracks, buckles, cracks and buckles, and twisted/distorted, respectively.

(D) Probable detail failure causes are estimated to be a combination of fatigue and the other factors indicated in the table by appropriate numbers as follows:

5. Shear
6. Tension
7. Combined Tension and Shear
8. Design
9. Fabrication/Workmanship
10. Welding
11. Neglect
12. Misuse/Abuse
13. Questionable
14. Heavy Seas
15. Collision
16. Other - See Notes

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TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Bulk Carrier	Fwd	30		30		60			
	Aft	200		200		620	12-C-6		
		70		70		120			
Naval	Fwd	20		20		30			
	Aft	80		80		150	12-C-6		
		30		30		70			
Tanker	Fwd								
	Aft	110		110		200	12-C-6		
Tanker	Fwd	400		400		800			
	Aft	60		60		100	12-C-7		
Bulk Carrier	Fwd	200		200		500			
	Aft	60		60		100	12-C-8		
Combination Carrier	Fwd	30		30		60			
	Aft	80		80		140	12-C-8		
Containership	Fwd								
	Aft	50		50		100	12-C-8		
Tanker	Fwd	50		50		100			
	Aft	410		410		800	12-C-8		
		90		90		200			
Tanker	Fwd	60		60		100			
	Aft	390		390		900	12-C-9		
		80		80		150			
Naval	Fwd								
	Aft	240		240		600	12-D-1		
Containership	Fwd	190	20	210	9.5	650	12-D-2	1	8,10,15
	Aft								
Tanker	Fwd	20		20		40			
	Aft	290		290		650	12-D-2		
		40		40		60			
General Cargo	Fwd	80		80		100	12-D-3		
	Aft								
Containership	Fwd	320	80	400	20.0	750	12-D-4	1	8,10,15
	Aft								
Combination Carrier	Fwd	70		70		130	12-D-5		
	Aft								
General Cargo	Fwd	20		20		20	12-D-5		
	Aft								
Combination Carrier	Fwd	40		40		100			
	Aft	110		110		200	12-E-1		
Containership	Fwd	40		40		50	12-E-1		
	Aft								
Containership	Fwd	90	10	100	10.0	120	12-E-2	1	12
	Aft								

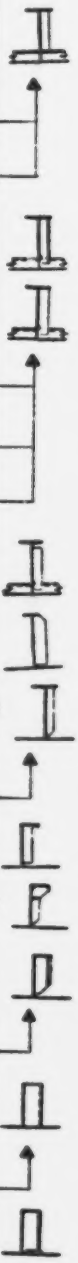

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TABLE A-12 DETAIL FAMILY: PANEL STIFFENERS

LOCATION ON SHIP / SHIP TYPE ↓		Number of Sound Details Observed	Number of Failed Details Observed	Total Number Details Observed	Percent Failures	Estimated Details on Ship	Detail Family Number	Failure Mode	Failure Cause
Containership	Fwd	60		60		80	12-E-3		
	Aft	80		80		120			
Containership	Fwd	59	1	60	1.7	100	12-F-1	1	5,10
	Aft								
Containership	Fwd	69	1	70	1.4	100	12-F-2	1	15
	Aft								
Containership	Fwd	76	4	80	5.0	100	12-F-3	1	7,8
	Aft								
Tanker	Fwd	20		20		50	12-F-4		
	Aft	60		60		100			
Containership	Fwd								
	Aft	88	2	90	2.2	200	12-F-5	1	7

NOTES:

(A) The above continued table gives information related to individual detail designs in the 50 ship survey.

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14. Heavy Seas
15. Collision
16. Other - See Notes

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Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)	2a. REPORT SECURITY CLASSIFICATION
Newport News Shipbuilding 4101 Washington Avenue Newport News, Virginia 23607	Unclassified
	2b. GROUP N/A

3. REPORT TITLE

IN-SERVICE PERFORMANCE OF STRUCTURAL DETAILS

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

Final

5. AUTHOR(S) (First name, middle initial, last name)

Charles R. Jordan
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6. REPORT DATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
March, 1977	188	16

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
NavShips No. 0935-00-042-5010 b. PROJECT NO. Ship Structure Committee Project c. Serial No. SF 43 422 706 06 Task 2002, SR-232 d.	N/A
	9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) J.O.2005-T

10. DISTRIBUTION STATEMENT

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11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
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13. ABSTRACT

This report includes the results of a structural detail survey of twelve families of approximately fifty different ships. Seven ship types were surveyed to determine whether or not predicted failures actually occurred.

The families are beam brackets, tripping brackets, non-tight collars, tight collars, gunwale connections, knife edge crossings, miscellaneous cutouts, clearance cuts, deck cutouts, stanchion ends, stiffener ends, and panel stiffeners. Fifty-six groups evolved with a total of 553 observed variations in structural configuration. The data are synthesized by family groups.

During the survey 490,210 details with 3,307 failures were observed. Eighty-two percent of the failures were in the cargo space and were predominately located in structure adjacent to the side shell. The remaining 18% were distributed, 10% forward and 8% aft of the cargo spaces.

Feedback data of this type should be invaluable to design and repair offices. It depicts, with sketches and photographs, the variations of structural configurations and tabulates all of the data collected

(See attached sheet for continuation)

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Detail Families structural detail failure survey detail failures cracks buckles design fabrication welding maintenance operation						

Continuation of Abstract

during the survey. As an aid to engineers and designers, failure causes such as design, fabrication, maintenance and operation are postulated. Systematic performance studies of this type should be conducted in all areas of ship construction.

METRIC CONVERSION FACTORS

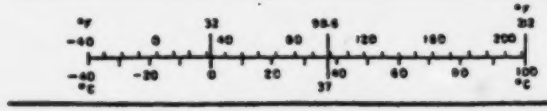
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
	AREA			
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
	MASS (weight)			
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
	VOLUME			
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
	TEMPERATURE (exact)			
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detail tables, see NBS Misc. Publ. 286, Units of Weights and Measures. Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
	LENGTH			
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
	AREA			
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
	MASS (weight)			
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
	VOLUME			
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
	TEMPERATURE (exact)			
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SSC-259, (SL-7-6) - *Verification of the Rigid Vinyl Modeling Technique: The SL-7 Structure* by J. L. Rodd. 1976. AD-A025717.

SSC-260, *A Survey of Fastening Techniques for Shipbuilding* by N. Yutani and T. L. Reynolds. 1976. AD-A031501.

SSC-261, *Preventing Delayed Cracks in Ship Welds - Part I* by H. W. Mishler. 1976. AD-A031515.

SSC-262, *Preventing Delayed Cracks in Ship Welds - Part II* by H. W. Mishler. 1976. AD-A031526.

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